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WOUNDS

MEDICAL AND SURGICAL THERAPY

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VOLUME III

WOUNDS

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WOUNDS

WOUNDS OF THE BLOOD VESSELS

WOUNDS OF THE ABDOMEN

WOUNDS OF THE SKULL AND BRAIN

BY

L. SENCERT
G. ABADIE
C. CHATELIN
T. DeMARTEL

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SECTION I

WOUNDS OF THE BLOOD VESSELS

WOUNDS OF THE VESSELS

CHAPTER I

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

1. Anatomical Description

WOUNDS produced by rifle-bullets, shrapnel-balls, and shell-splinters vary greatly from one another. In the case of the arteries, the wounds caused by rifle-bullets may be lateral and partial, complete and circumferential, or perforating.

Lateral wounds are caused by projectiles striking the outer third or fourth of the transverse diameter of the vessel (fig. 1). The adventitia, the middle and the internal coats, are lacerated, whilst radiating rents of the intima, of varying extent, prolong the external lacerations along the interior of the vessel. The retractility of the middle coat tends to separate the lips of the vascular wound, and also to cause a slight change in the axis of the vessel, so that the segments above and below are deflected towards each other, thus forming an obtuse angle with the wound at its apex (fig. 1). This double action of the middle coat results in an enlargement of the lateral wound.

which continues to gape, thus encouraging hæmorrhage. These lateral wounds vary in size from a mere slit to complete division of the vessel (fig. 2).

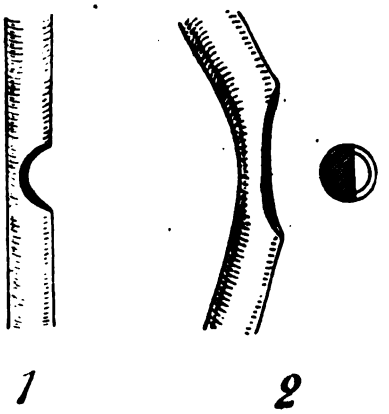

FIG. 1.—Diagram showing lateral wound of an artery.

Complete division, even of the large vessels, is more frequent than one would suppose, and is almost the only kind of wound met with in medium-sized arteries. Its frequency in large arteries is explained by the fact that at short range the explosive effect of the bullet is such, that the artery traversing its track is extensively torn and broken up, sometimes with great loss of substance (fig. 3).

FIG. 2.—Diagram showing two lateral wounds of an artery.

I saw a young soldier who had been wounded by a bullet, which entering the right buttock emerged at the level of Poupart's ligament, encountering the femoral artery on the way. The vessel was broken up; there was a gap of two inches between its upper and lower extremities, and these were very much frayed (fig. 4).

At medium or long range, on the other hand, the bullet is less stable, and is, in consequence, very easily diverted. Hence, instead of being

struck normally by the point, the arterial wall is hit more or less obliquely by the side of the bullet, which tears it in the same way as a large projectile.

For the same reason, few perforations are met with in arteries, and then only in the larger trunks. Figs. 5 and 6 show a perforation of the common iliac artery and one of the common carotid by rifle-bullets. These perforations are smaller when the velocity of the bullet is low. Their diameter always appears less than that of the bullet. This is due to the fact that the artery is forced back and stretched before being pierced, in such a way that, when the bullet has passed and the vessel recovers itself, the edges of the wound come together, and the extent of the lesion is lessened. Sometimes the perforation is situated in the middle of the vessel, and sometimes nearer one margin, when it closely resembles a lateral wound (fig. 7).

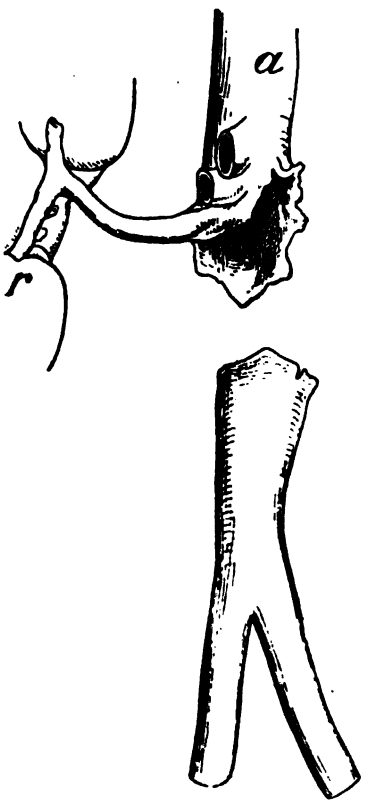

FIG. 3.—Complete division of the abdominal aorta by a rifle-bullet. Lesion of the renal artery. (Latarjet's case. Val-de-Grâce Museum.)

In the veins, also, lateral wounds, complete division or perforation, are produced by rifle-bullets. The

vein is less elastic than the artery, and ruptures

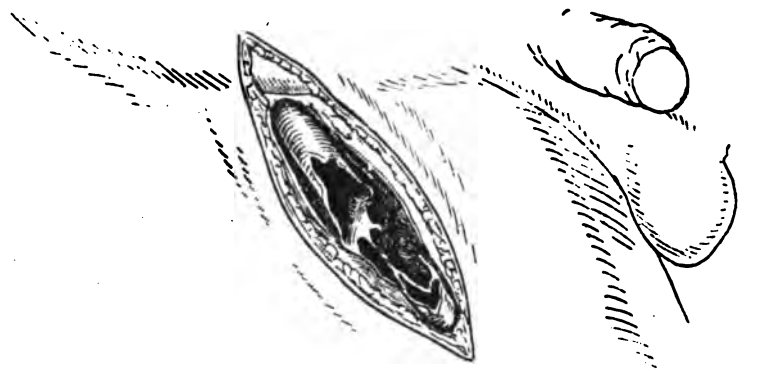

FIG. 4.—Complete section of the femoral artery by a rifle-bullet. (Author's case.)

rather more easily in consequence. Contrary to what might have been expected from previous experience, complete rupture of the companion vein is often seen in conjunction with a lateral wound of the artery. The ends of the divided vein are clean and hardly lacerated at all, and their walls come together without retraction of the internal coat. Lateral wounds and perforations are also met with. When a bullet passes between an artery and a vein, it may leave a lateral wound of both. In such a case the

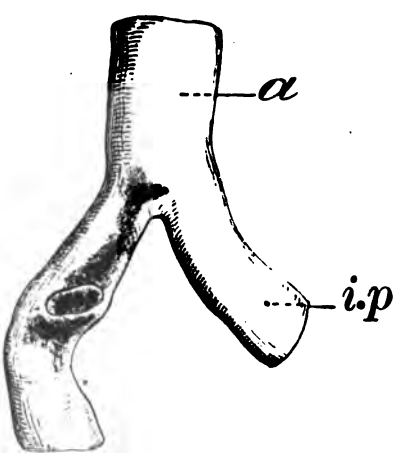

FIG. 5.—Perforation of the right common iliac artery by a rifle-bullet. (Latarjet's case. Val-de-Grâce Museum.)

openings face each other, and adhere by their margins immediately after the passage of the missile.

As a matter of fact, associated wounds of both artery and vein are very frequent. Isolated injury of either vessel may of course occur, but they are more often found together. Any of the varieties of injury may be found in combination.

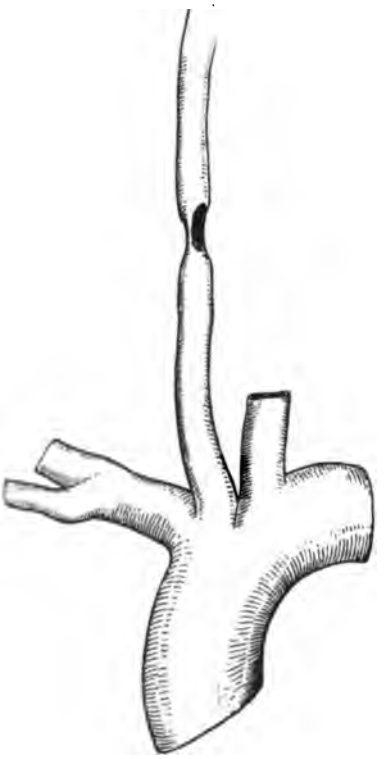

FIG. 6.—Perforation of the left common carotid by a rifle-bullet. Death almost immediate. (Latarjet's case. Val-de-Grâce Museum.)

FIG. 7. — Diagram showing lateral perforation of an artery.

There may be a perforation of artery and vein, complete division of both vessels, or a lateral wound of each (figs. 8 and 9).

One very important point, to which I particularly wish to direct attention, is the number of vessels which may be injured by the same projectile. Not only the

artery and its companion vein may be wounded, but also collateral branches arising below the point of injury and situated on a deeper plane, or a bifurcating branch may have been struck behind the chief trunk. I have seen the vertebral artery wounded together with the common carotid, and the

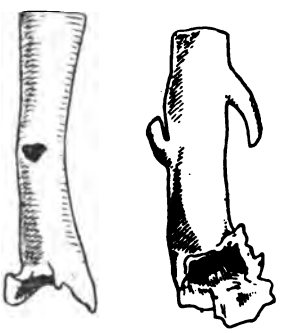

FIG. 8.—Wound of the femoral vessels by a shrapnel-ball at the level of the crural canal.

Artery and vein are both completely divided. The artery shows a lateral wound above the level of complete section. (Latarjet's case. Val-de-Grâce Museum.)

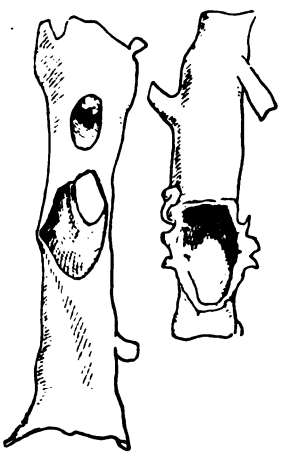

FIG. 9.—Lateral wound of the external iliac artery, with multiple perforations of the vein by shell-fragments. (Latarjet's case. Val-de-Grâce Museum.)

deep with the superficial femoral. Quénu saw the trunk of the interosseous divided at the same time as the brachial in the bend of the elbow. In operating for a hæmatoma in Scarpa's triangle, P. Duval found a rent in the deep femoral vessels, as well as a wound of the superficial femoral artery and vein. This multiplicity of lesions, which is associated with shell-fragments as well as with bullets, has a considerable therapeutic importance. As a matter of fact, it is

one of the chief reasons for preferring ligature in the wound itself to tying the vessels above the injury.

Fragments of shells, grenades, and aerial torpedoes also cause vascular wounds of widely varying types. I have seen actual punctures from minute, sharp fragments of a grenade. Sometimes the fragment

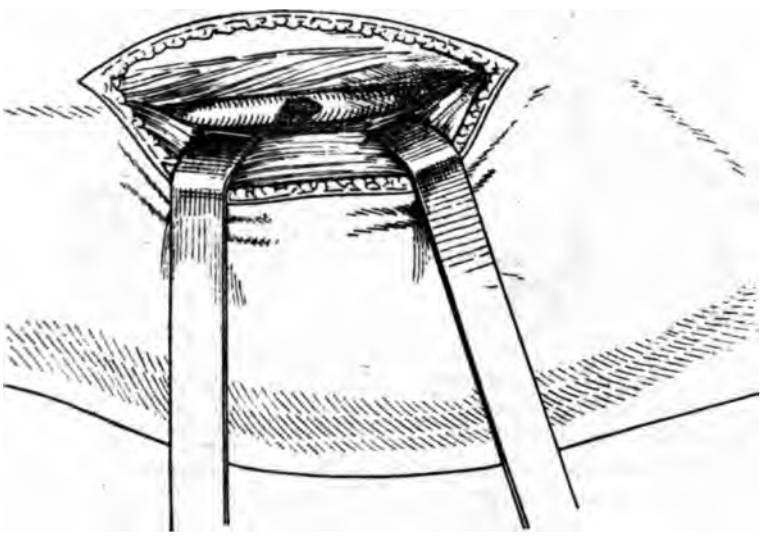

FIG. 10.—Lateral wound of the posterior tibial by a grenade-splinter. The splinter is seen lodged in the wound, which it occludes. (Author's case.)

remains fixed in the wall of the vessel. Fig. 10 shows a small grenade-fragment impacted in the lumen of the posterior tibial artery, the case having shown no symptom of arterial injury. On opening up the wound I came upon the posterior tibial, and found the splinter fixed in its wall. More or less extensive lateral tears, which may even amount to complete rupture, are sometimes observed; or there may be true perforation. This last, however, is obviously a rare lesion, since it implies a very small splinter

and a large vascular trunk. I have seen it (fig. 11) in the carotid trunk, which was perforated through

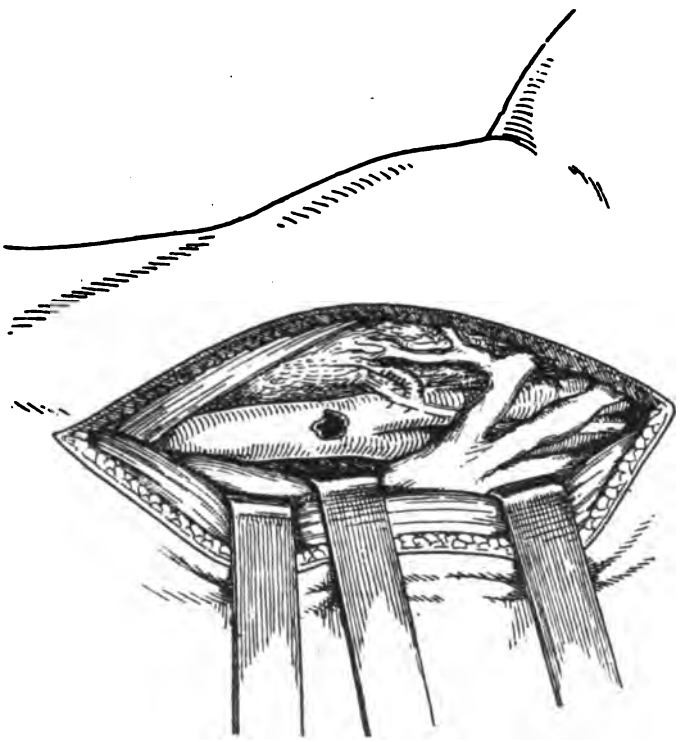

FIG. 11.—Perforation of the carotid bulb by a shell-fragment. (Author's case.)

and through by a sharp fragment the size of a lentil, which fragment I removed from the posterior opening in the vessel, where it had lodged. Lastly, there may be complete division or crushing, as in cases where the limbs are torn off or severely crushed by large fragments of shell or by minor projectiles. On the surface of the stump, or at the bottom of the extensive wound, may be seen the artery and vein,

sometimes gaping, more often lacerated and flattened, but not bleeding.

Such, briefly, are the principal types of war-wound presented by the vessels. It is, however, essential that vascular lesion should not be regarded as constituting in itself a clinical entity. Its course is determined as much by the general characters of the wound as by the specific nature of the vascular injury.

It is hardly necessary to point out that bullet-wounds differ entirely from those caused by shell-fragments. As a general rule, if the range is fairly long, bullets cause simple puncture of the tissues; the orifices of entrance and of exit are punctiform, and the whole track, subcutaneous, aponeurotic, and muscular, is barely visible on operation. The tissues, separated for a moment, close up in normal position and resume their normal relationships directly the bullet has passed. There is no foreign body in the track, because the bullet penetrates the clothing by severing the threads and pushes no débris before it. Such wounds are generally slight, and are not septic.

Shell-wounds, on the contrary, are very different. Anatomically they may be broad or narrow, but they are never punctiform; physiologically they are contused and septic.

The cutaneous opening is irregular, with contused and lacerated edges exuding, often very copiously, a sanguineous fluid. Beneath the skin the cellular tissue is lacerated; the aponeurosis, either torn or simply perforated, covers a deep and tortuous cavity in which the muscle lies contused and crushed. Contusion and sepsis are the leading characteristics of

such wounds. The contusion is so great that the edges of the wound, the cellular tissue, the aponeurosis, and the muscles constituting the walls of the bullet track, are devitalised at once. The degree of contusion may extend even to actual mortification of the tissues. The extent of the contusion is always greater than the apparent limits of the wound; it includes, to a varying depth, the whole length of the track, whether subcutaneous, muscular, or osseous.

Infection is conveyed directly by the agency of the projectile and the débris which it carries with it. As these jagged fragments pass through clothing, leather accoutrements, and even note-books, they drive before them a thousand septic particles which they deposit along the entire length of their track, burying the largest at the very bottom of the wounded area. Thus an admirable incubation chamber for microbes is formed, where in a closed tube, protected from air and light, germs may multiply at their ease.

Thus the course of the vascular lesion is determined by the general characteristics of the wound.

2. Anatomical and Physiological Course

The anatomical and physiological development of bullet-wounds differs from that of shell-wounds.

A. Bullet-wounds.—As soon as the artery is wounded the blood escapes and is effused round the vessel. The first obstacle which it meets with is the perivascular sheath, supported and kept rigid by the neighbouring tissues. The bullet in its passage does not destroy this barrier; it separates a few muscular fibres, which come together again after it has passed.

There is no bullet track, and no wound cavity. Thus the blood immediately encounters powerful barriers which prevent it from spreading very far. Hemmed in thus, the blood in the immediate neighbourhood of the vessel coagulates rapidly, and the clot thus formed closes the arterial wound like a plug or cork (J.-L. Petit).

The anatomical conditions of the wound are much more favourable to this spontaneous hæmostasis when there is complete division of the artery instead of a lateral wound. In the former case the retraction and curling up of the middle and internal coats within the adventitia obliterates the lumen of the artery, whereas in the case of the lateral wound there is retraction of the internal coat only, which tends to render the wound more gaping.

This preliminary hæmostasis once established, cicatrisation of the vascular wound goes rapidly forward. The small fibrous parietal cicatrix or the two terminal cicatrices, as the case may be, are rapidly lined by proliferation of the endothelial cells. This spontaneous repair has been verified by both clinical and operative observations. Cases of arterial bullet-wound have been observed which for some time presented all the stethoscopic signs of arterial or arterio-venous lesion, and which healed so completely that no trace of murmur was distinguishable. Moreover, the existence of spontaneous arterial cicatrices has been afterwards verified by operation. Le Jemtel has reported a case of cicatrisation of both ends of the axillary artery divided by a ball which also damaged the nerves in the axilla. Lexer, operating upon a man three weeks after he had sustained a paralysis of the ulnar, found a lateral cicatrix in the

brachial artery which had reduced the calibre of the vessel to one-half. In another case the same surgeon found the brachial divided, and each end spontaneously healed.

Most frequently, however, things do not fall out so happily. Under the influence of the repeated pulsations, the blood extravasated outside the vessel tends gradually to infiltrate beyond the sheath into the intercellular spaces and the interstices of neighbouring muscles. Once the cellular tissue has given way, the infiltration continues until the pressure of the extravasated fluid equals the arterial tension. Owing to the fact that the wounds in the different tissue layers do not correspond, the blood does not reach the cutaneous wound and cannot escape externally. Thus a diffuse arterial hæmatoma is formed. If the vessel is subcutaneous or superficial, like the femoral in Scarpa's triangle or the brachial at the bend of the elbow, the hæmatoma is superficial, and forms a tumour visible to the eye. But if the vessel is deep, like the popliteal or the posterior tibial, the hæmatoma is infiltrated into the interstices of the deep muscles, distending and swelling the limb, but not forming a visible tumour. In some cases, by following the adventitia of collateral vessels, it may pass from one muscular layer to another. Thus a diffuse hæmatoma of the superficial femoral may extend into the region of the adductors, and thence, by following the course of the perforating arteries, it may reach the posterior aspect of the thigh. In other cases the hæmatoma may be multilocular in character, presenting an anterior and a posterior sac separated by a muscular wall. Hæmatomata of this kind are seen in the thigh when the deep and

the superficial femoral are both wounded at the same time.

This periarterial effusion of blood is variously termed diffuse aneurism, false aneurism, diffuse aneurismal hæmatoma, or pulsating hæmatoma. These designations all appear to me to be meaningless. I agree with Monod that there are grounds for describing the condition as arterial hæmatoma, the name given it originally by Cruveilhier.

As the result of contact with the limiting tissues the blood gradually coagulates at the periphery of the effusion. The coagulated blood contracts, the irregular prolongations of the effusion are reduced, and, as the hæmatoma becomes established, it takes on a certain regularity. It is like a river in flood which, after spreading far and wide, gradually withdraws, and at a given moment settles down into its permanent bed. The irritation set up by the clot in the neighbouring tissues gives rise to an infiltration of serum and leucocytes, which at first forms a sort of œdematous perihæmatic mass, and later a firm lardaceous wall, which, by a progressive tissue organisation, becomes gradually differentiated in proportion to the age of the hæmatoma. At the same time a white lamination, lining the internal surface of the sac, and giving it the appearance of a vessel wall, is deposited by clots. It is owing to this phenomenon that a hæmatoma is sometimes mistaken for true aneurism. As a matter of fact, there is no true aneurismal wall which may be isolated and removed. Up to at least the fifth week this pseudo-sac may be made to disappear by pressing out the clots from inside it. It is not an aneurism; it is an encysted arterial hæmatoma.

How does this arterial hæmatoma terminate? Most frequently the inflammatory connective-tissue wall becomes defined and hardened, and the peripheral layers of the clot become laminated and adherent to it; the centre of the hæmatoma, on the other hand, which is close to the arterial wound, and is continuously under the influence of the systolic pulsations, becomes softened, and is gradually hollowed out into a regularly shaped cavity, into which the blood-stream enters with each heart-beat. The pressure of the circulating blood against the wall of this cavity causes it to become thinner, and it is more or less completely lined by an endothelial proliferation from the edges of the arterial opening. In this manner a sac with organised walls, lined with endothelium, and bounded by a progressively defined connective-tissue sac, is formed round the vessel. It is in direct communication with the interior of the artery, and pulsates synchronously with it. It is evident from the nature of these characters that the condition is now one of true arterial aneurism.

Unfortunately, however, even in the case of bullet-wounds, this favourable course is only too frequently interrupted by the occurrence of very serious complications. These may arise from two causes, namely, the progressive growth of the hæmatoma, and its infection. The anatomical and clinical significance of these facts will be considered later.

The development of an arterial bullet-wound is not quite the same when accompanied by a wound of its companion vein.

1. The first group of cases comprises those in which the bullet passes between the artery and the vein and inflicts a lateral wound on each. The two orifices

correspond exactly, and, from the beginning, they adhere so accurately and so completely by their margins, that there is no appreciable effusion of blood around the vessels (fig. 12). From the beginning of the war the base hospitals have reported many of these cases of arterio-venous communication. This exact correspondence of arterial and venous perforation cannot, however, be very frequent. The resistance of the walls to the projectile is not the same in the two classes of vessel, and their retractility is also different. Where the two openings do not exactly correspond we have the beginnings of an arterio-venous hæmatoma. But the extravasated blood finds the central end of the vein so easy of access that it is rapidly taken up by it, and nothing remains but a slight effusion in the perivascular sheath.

FIG. 12.—Diagram showing the direct communication of an arterio-venous wound.

Cicatrisation of the two wounds is accomplished by an endothelial proliferation, which quickly unites the edges of the fistula. Between the two vessels, above and below the opening, the blood in the sheath takes part in the organisation of a fibrous tissue which unites the arterial and venous walls for a distance of an inch or more. This adhesion of the two vessels is of great importance. It prevents both the ligaturing of the communication and the reconstitution of the two vessels by a double suture. One invariable and immediate consequence of arterio-venous communication is dilatation of the central

and peripheral ends of the vein in the neighbourhood of the union. The violent projection of blood towards both ends of the vein enormously increases the venous tension. The vein dilates and thickens, thus presenting the characteristic features of aneurismal varix (fig. 13). The dilation may be regular and spindle shaped, or it may become irregular and bulging in

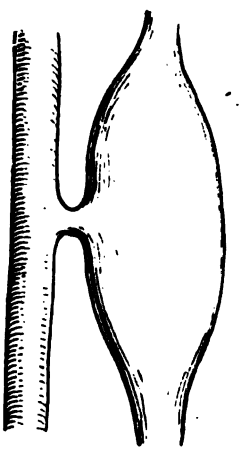

FIG. 13.—Diagram showing aneurismal varix. The vein is evenly dilated.

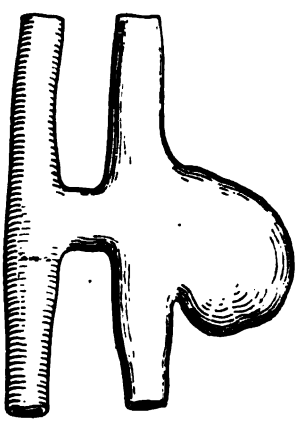

FIG. 14.—Diagram showing arterio-venous aneurism. The sac is entirely venous.

the form of a sac (fig. 14). The central end of the artery, meanwhile, undergoes considerable modification. It becomes thin and atrophied; it loses its tension, and dilates in its turn. This, in its simplest form, is the condition termed arterio-venous aneurism.

2. In the majority of cases the arterial and venous lesions are more complex, but their course is practically the same. Sometimes there is a double perforation of artery and vein; sometimes a lateral wound of the artery with complete division of the vein, or *vice versa*;

sometimes complete division of both artery and vein. In every case we find, immediately after the passage of the bullet, a hæmorrhage both arterial and venous, which spreads around the vessels, inside and outside the adventitia, like a diffuse arterial hæmatoma. Owing to the ease with which the blood passes into the central end of the vein this effusion is never very

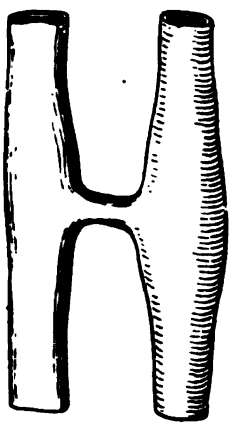

FIG. 15.—Diagram showing arterio-venous aneurism. The two vessels are united by a small fibrous canal.

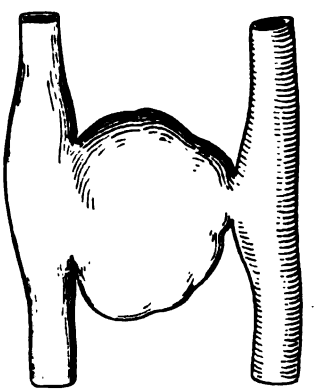

FIG. 16. — Diagram showing arterio-venous aneurism with an intermediate sac.

extensive. Moreover, the hæmatoma is soon bounded by an inflammatory wall, the formation of which is not hindered, as it is in arterial hæmatoma, by the pulsation of the blood. Thus the brief stage of diffuse hæmatoma gives place to that of an encysted hæmatoma, the centre of which is a channel of communication between the artery and vein. In the simplest cases the intermediate hæmatoma undergoes progressive retraction, until operation shows only a small fibrous canal, about half an inch in length, uniting

the two vessels (fig. 15). In other cases the vessels are united by a true sac, the wall of which becomes gradually isolated and differentiated until it can be removed in its entirety (fig. 16). Finally the conditions are very much complicated by dilatation of the central end of the vein. The gravest complications occur, however, where communication takes place in the vicinity of a tributary vein, for here very considerable modifications of form and dimension are effected, which influence the whole of the neighbouring vascular system. Under such circumstances as these the arterio-venous aneurism assumes forms and relationships which it is most difficult to foresee, and it occurs in all possible varieties, from the simplest aneurismal varix to the most complex varicose aneurism.

B. Wounds from Shell-splinters.—These are of two kinds :—

1. Those in which the external wound gapes widely.
2. Those in which it is partially or completely obliterated.

1. *Extensive wounds.*—When the wound corresponds to extensive loss of skin and muscle caused by a large splinter it gapes widely ; when due to a comminuted fracture with much cutaneous and muscular laceration, or to the loss of the whole or a portion of a limb, it gapes very widely.

The blood flows out immediately the vessel is opened, and the external hæmorrhage is often sufficient to cause instant death on the field. Sometimes the vascular wound communicates with one of the large cavities, such as the pleura or peritoneum, when death may follow quickly as the result of internal hæmorrhage. We shall return later to a consideration of these points.

There are various factors, however, which tend to check this dangerous hæmorrhage. Diminution of the arterial tension due to acute anæmia, retardation of the blood flow, and syncope are conspicuous, and perhaps secondary, causes. In my opinion, the high degree of contusion of the vessel in the neighbourhood of the actual wound supplies the primary cause. I have had men brought to my ambulance with great ragged wounds at the root of a limb, with the fore-arm, arm, or leg crushed or torn off, and have found no sign of hæmorrhage on removing the dressing. On carefully cleansing the wound and removing the clots from its depths the femoral, popliteal, or axillary artery is found to be wounded laterally, ruptured, torn or lacerated. The wound is closed by a clot, already firm and adherent. Where division is complete, the lumen of the artery is blocked by the external coat stretched in front of the inner coats, which are retracted inside the sheath. On carefully examining lesions of this kind, the middle and internal coats are found mangled and frayed, with hanging shreds which adhere together, favouring the obliteration of the vessel. A protecting clot is thus often formed extending an inch above the wound. On two occasions I saw the axillary artery apparently gaping at the bottom of the axilla without the emission of a single drop of blood. On passing a grooved director into the central end of the vessel I ascertained that it was closed a little distance above. These conditions are readily explained by the high degree of crushing and contusion by which shell-wounds are accompanied. The distant disturbance caused by the striking of the projectile, together with the direct shock and the elongation of the vessel, explains the extent of the

arterial contusion. That the vessel should be affected in the same way as everything else in the track of the missile is not surprising.

This hæmostasis is in its nature very precarious, and the least shock, the slightest movement, sometimes a mere increase in the blood-pressure, may, some hours after, displace the clot and set up a fresh hæmorrhage, called reactionary hæmorrhage.

What happens to this gaping wound, at the bottom of which a large vessel is injured? Nine times out of ten the vascular wound is recognised and complications are averted by suitable treatment. But it may happen that it is not recognised, and the case may be regarded as one of simple injury to the soft parts. Now it is well known that all such wounds are contused and septic, and that the degree of the infection is determined solely by the local condition of the wound. A surface wound, such as that under consideration, open and gaping and exposed to air and light, however much fouled it may appear to be, will never become the seat of serious and rapid sepsis. It can never, as in the case of the narrow, confined wound, become a closed chamber for the multiplication of germs, and it is only exceptionally that gangrene and diffuse suppuration are found in it. A simple localised infection during the progressive elimination of the contused walls of the injured area is all that is usually presented.

After eight, ten, or twelve days it is not unusual in these conditions for a secondary hæmorrhage to occur. This may be fatal at once, or it may recur in successive bouts, terminating in death. These secondary hæmorrhages depend upon several factors: the vascular wall, severely bruised for some distance

from the wound, may necrose gradually, and, when the slough separates, it may open the vessel above the obliterating clot. On the other hand, the clot itself, soaked in the septic fluids stagnant in the wound, may gradually soften and become less adherent to the edges of the wound; a sudden movement, a change of position on the part of the patient, may serve to detach it, and so open up the vessel either partially or entirely.

The normal course, then, of shell-wounds which are extensive from the beginning leads to hæmorrhage, which may be primary, reactionary, or secondary.

2. *Punctured wounds.*—The conditions are quite different when the wound is narrow and confined. If the course of the projectile is very oblique, if the cutaneous and vascular wounds do not directly correspond, or if foreign bodies, such as clothing or fragments of muscle and aponeurosis carried by the projectile, block the track, the blood flowing from the vessel cannot readily escape externally. There may be some bleeding, but it will not be the external hæmorrhage of extensive wounds. The blood is extravasated round the vessel and its adventitia. Its rapid effusion is favoured by the existence of a true traumatic area, a ready-made cavity hollowed out at the expense of the muscles and the torn aponeuroses. Thence it filters into the muscular sheaths and under the aponeuroses, which it raises and distends, and it fills all the spaces which are free or distensible for some distance above and below the wound. In this way a diffuse arterial hæmatoma is formed, sometimes of enormous size.

It must not be imagined, however, that the arterial hæmatoma always reaches that enormous size at once.

The contusion of the vessel and the extensive laceration of the internal coat for some distance from the wound greatly facilitate arterial thrombosis and spontaneous hæmostasis. The area of the wound is hardly filled with clots before the bleeding stops and the swelling ceases to increase. I have several times been surprised to discover, at the bottom of a wound containing a few clots, in the popliteal space or on the internal surface of the thigh, a wound of the femoral or popliteal artery temporarily obliterated by a thrombus.

Nevertheless the arterial hæmorrhage is generally very large, and coagulation does not take place until the effusion has attained considerable dimensions. The more slowly it forms the further it extends into the central end of the vessel, until it reaches to the nearest collateral branches, which it obstructs, thus adding to the causes of rapid gangrene of the wounded limb. The principal trunk being obliterated, circulation can be carried on only by the collaterals above and below the perforation. But the clot often obstructs the origin of these collateral branches, and the powerful pressure of the effusion obliterates them in their length, so that the conditions for the re-establishment of the circulation are extremely unfavourable.

We have to deal, moreover, with a septic wound. The conditions in this case are the reverse of those accompanying extensive wounds, and are extremely favourable to the rapid development of sepsis. At the bottom of this bruised and ragged cavity, protected from air and light, in the midst of clots which readily become putrescent, the germs conveyed by the projectile and by fragments of clothing multiply with

great rapidity. From the beginning infection is very severe, and is frequently accompanied by the evolution of gas, which is given off into the wound. The increased distension occasioned by the gas completes the blocking of the collateral vessels, and from this moment gangrene becomes inevitable. It is a gangrene due to causes both direct and indirect, mechanical and septic, and its appearance immediately endangers life.

Sometimes, however, the sepsis is not at first so severe. Instead of an anaerobic infection leading to gas gangrene or gaseous cellulitis, a simple, slow phlegmonous inflammation leading to simple suppuration of the hæmatoma may develop. This suppuration occurs chiefly when the hæmatoma is comparatively small. Large hæmatomata place life and limb too speedily in danger to allow of slow complications such as this. Small hæmatomata, on the other hand, which are often unrecognised, give rise to local septic conditions, which range from a simple inflammation to suppuration which is either diffuse from the outset or becomes so. The condition terminates very naturally in secondary hæmorrhage. The extravascular and the arterial clots become softened and separated from one another by the course of the infection; the vascular wound is suddenly left gaping, and external secondary hæmorrhage, which rapidly proves fatal, is the result.

Thus the normal course of shell-wounds, when they are narrow and restricted, leads to septic arterial hæmatoma. When this is considerable, it leads to septic gangrene; when it is small, to local sepsis and secondary hæmorrhage.

CHAPTER II

CLINICAL AND THERAPEUTICAL CONSIDERATIONS

1. *Extensive Wounds*

These include extensive loss of the soft parts, caused by a ricochet bullet, a shell-splinter, or a minor projectile; perforating wounds from short-range bullets with explosive effects; and laceration with or without loss of a portion of a limb. The implication of large vessels in such wounds results in copious external hæmorrhage.

External Hæmorrhage. — Hæmorrhage from a wounded artery is very profuse. The blood is bright red in colour, and spurts from the wound in jets, sometimes even bubbling. The hæmorrhage is controllable by compression of the limb above the wound. Sometimes, however, as in certain wounds of the hand, forearm, or face, compression between the wound and the heart fails to arrest the bleeding, the blood escaping equally from the central and peripheral ends of the divided artery.

In the case of a large vein the blood is dark red, almost black, in colour, and flows either in a steady stream, or in a large continuous jet, which may be projected for several inches. Muscular contractions,

straining, or the effects of expiration may give the jet a misleading appearance of pulsation. The bleeding in this case may be lessened or arrested by compression below the wound. Sometimes, however, as in the case of a large vein at the root of the neck, compression between the periphery and the wound does not arrest the hæmorrhage, as the blood continues to escape from the central end of the vein.

Finally, where both an artery and its companion vein are involved, as they frequently are, the pulsating arterial jet predominates, while the venous blood flows in a sheet over the whole surface of the wound.

Death may ensue rapidly, sometimes in a few seconds, as the result of abundant hæmorrhage, and it is only those in the immediate neighbourhood of the patient who can do anything to arrest it.

Sometimes, however, in spite of the absence of immediate treatment, a large vascular wound does not prove fatal. Emotion, fright, pain, and the rapid fall of blood-pressure may cause syncope. The patient becomes very pale, the eyes turn up, and he loses consciousness. The flow of blood is retarded, a clot forms in the hole in the vessel, and the hæmorrhage ceases.

This spontaneous hæmostasis is favoured by certain contributory circumstances. It is more frequent in complete division than in lateral wounds. The degree of contusion of the vascular walls is an important factor; the more the artery is bruised and lacerated, the further do the lesions of the internal coats extend into the lumen of the proximal segment, and the sooner, in consequence, does thrombosis occur.

Thus it happens that many cases of serious lesion of main vessels are brought alive to the dressing

station. Indeed, one might be almost tempted to believe that spontaneous hæmostasis is very frequent, if one did not remember how many there must be in whom it has not taken place, and who have died on the field.

I myself have seen a score of cases in which the axillary, femoral, or popliteal vessels lay extensively injured at the bottom of a gaping wound, and yet, in spite of the absence of ligature or other preventive treatment, there was no hæmorrhage.

Acute Traumatic Anæmia.—When a patient is brought to the dressing station some hours after injury with an extensive wound, accompanied by serious vascular injuries which are no longer bleeding, the general symptoms are unmistakable. The face is pale and bathed in sweat; the lips and conjunctivæ are colourless; the look is vacant; the voice feeble; the body and limbs are completely motionless; consciousness is dulled, and the patient makes no complaint; the pulse is small and rapid, 120 to 130; the respiration is short and shallow; the nose and extremities are cold. Sometimes the patient shows slight agitation, and complains of being unable to see, of buzzing in the ears, of suffocation, vertigo and dizziness. All these symptoms are those of acute anæmia. The mere sight of such a completely exsanguine patient makes the diagnosis obvious. It is not necessary to remove the dressings to know that there is injury of one of the great vessels.

Exposure of the wound confirms the diagnosis. Excluding the cases in which a limb has been torn off or crushed, exposure will reveal an extensive wound of the axilla, of Scarpa's triangle, or of the popliteal space filled to overflowing with red clots,

with a small thread of venous blood trickling from the inferior angle. It is important that the dressing should not be removed nor the patient disturbed until everything is in readiness for operation, the early steps of which will serve to confirm the diagnosis.

If left to themselves these cases are doomed to almost certain and speedy death, which may supervene without fresh hæmorrhage, from increasing weakness passing into fatal syncope. The patient continues pale and colourless, the sight becomes more and more dim, the buzzing in the ears louder; the respiration becomes more and more superficial, the pupils dilate, and the pulse becomes too rapid to count and almost imperceptible. Gradually consciousness fails, leaving only the reflex action of respiration, which becomes progressively weaker, irregular and unequal. It stops altogether, is resumed once or twice, and finally ceases entirely.

The extreme gravity of these anæmic conditions, even when they do not seem to threaten immediate death, cannot be overestimated. A patient who had bled a great deal, but was bleeding no longer, was brought to my ambulance with an extensive wound below the clavicle and division of the axillary vessels. The wound was cleansed, both ends of the artery were tied without the loss of a drop of blood, and a dressing was applied. The patient did not rally; he became gradually weaker, and died three hours later. A vigorous soldier had the head and the upper part of his humerus shattered and his axillary vessels torn. There was no hæmorrhage, and the degree of anæmia apparent was not sufficient to contra-indicate the operation. The shoulder was disarticulated without perceptible loss of blood, yet he died two hours

later. I could give many examples of the great importance attaching to these anæmic conditions in the immediate prognosis of wounds. One is too apt to say that the patient is safe because he is not losing blood, that the artery is tied and will bleed no more. But death will often follow in a few hours without further hæmorrhage. There is a certain degree of anæmia from which the organism cannot rally. By means of the treatment which we shall consider presently the general condition may be improved and the symptoms relieved, but all the ground gained in half an hour may be lost again in a few minutes. One of my assistants, Dr Joussemet, has studied the arterial tension with Vaquès' apparatus in a large number of cases. It is his opinion, and one which I heartily endorse, that there is a minimum below which arterial tension cannot fall without a fatal result ensuing.

Reactionary Hæmorrhage.—In contrast to the cases where death occurs from primary hæmorrhage without further loss of blood, there are others who succumb to reactionary hæmorrhage after some hours of temporary arrest of the bleeding. It is obvious that spontaneous hæmostasis is a very precarious affair. The clot by which the hæmorrhage is arrested is very easily displaced by a sudden movement, a blow, a strain, a rise in the blood-pressure, or recovery from syncope. How many deaths from delayed hæmorrhage must have taken place between the field of action and the dressing station, or between that and the casualty clearing station! In September 1914 a strong young soldier was struck by a shell-splinter which divided the femoral artery; he fell and lost consciousness. He was picked up with no sign of

hæmorrhage, and brought to my ambulance. On the way he gradually recovered consciousness, and on arrival thought himself strong enough to walk alone. But at the first step a violent hæmorrhage through the dressing took place, and before he reached the operating theatre he was dead. I could give many similar examples of the precarious nature of spontaneous hæmostasis. In nearly every case it leads to delayed hæmorrhage.

Thus the majority of those who sustain a wound of one of the larger arteries succumb to external hæmorrhage on the field. Those who escape immediate or rapid death are liable to die during their transit from the trench to the dressing station, or even after reaching it, from reactionary hæmorrhage or acute anæmia.

Indications for Treatment

The treatment of large wounds consists in the immediate arrest of the external hæmorrhage, the prevention of reactionary hæmorrhage, and the management of the profound anæmia. By what practical measures are these results achieved?

A. In the Trench and at the Aid-post.—The only medical persons who have the opportunity of seeing and treating urgent external hæmorrhage are the regimental hospital orderlies always present with the infantry in the trenches, the divisional and regimental stretcher-bearers who carry away the wounded when they fall, and the medical officers attached to the infantry units. The method of procedure is as follows:—

If the wound is situated below the root of a limb,

the first idea of the wounded man, his comrade, or anyone else who witnesses a severe and threatening hæmorrhage, is to apply a constricting band between the wound and the heart. The elastic bandage found in the stretcher-bearer's bag, a napkin, a handkerchief, the wounded man's necktie, or a bootlace, are usually employed for this purpose, a piece of wood, a stone, or a lump of turf being slipped between the

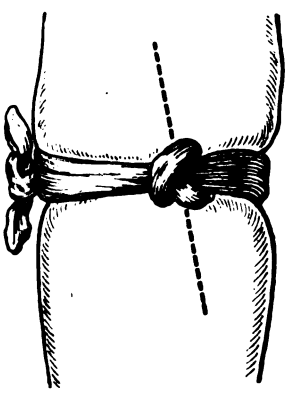

FIG. 17.—Mayor's tourniquet. (After Toubert.)

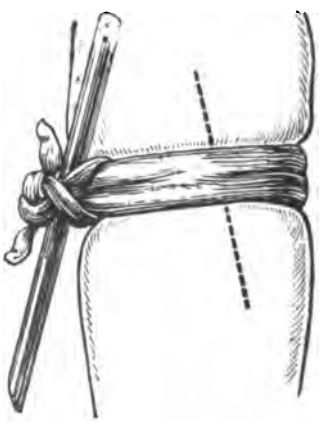

FIG. 18.—Morel's emergency tourniquet. (After Toubert.)

band and the skin to convert the former into a tourniquet. One cannot but admire the ingenuity which can create a pressure pad and the tourniquet of Mayor or Morel (figs. 17 and 18) out of nothing, and thus in many cases avert a serious external hæmorrhage.

It is obvious that in the trenches, on the field, and even at the aid-post, temporary arrest of hæmorrhage is the most that can be accomplished. The best method of effecting this is by compressing the limb above the wound. But it must be borne in mind that a tourniquet should never be applied unless it

is either certain or very probable that there is a wound of a large artery. Too many people—hospital orderlies, stretcher-bearers, and even medical officers—mistake the bleeding which occurs in all wounds for arterial hæmorrhage, and apply the tourniquet to all indiscriminately. Now the application of a tourniquet may constitute a grave danger to both life and limb. The danger is relatively insignificant if the constriction is soon removed, but constriction is serious if it becomes prolonged. The cessation of both arterial and venous circulation, the sudden interruption of all trophic stimuli through compression of the nerves, and the starving of the tissues by the pressure of an overtight band are all conducive to gangrene of the portion of the limb thus isolated. Moreover, the missile deposits on the surface of the wound numerous germs, the propagation of which is favoured by the devitalised and anæmic condition of the tissues. Under these circumstances the frequency with which gangrene, both mechanical and septic, follows the application of the tourniquet is not to be wondered at. The method is in fact justly regarded as one of the chief contributory causes of gas gangrene. It should be employed only with the greatest discrimination, and should be confined to large wounds from which the blood escapes in forcible jets, the unmistakable sign that an important artery has been injured. When a tourniquet has been applied, a special label should be attached, in order that those at the dressing station may at once recognise that the case is not suitable for evacuation. These cases should be conveyed as soon as possible to the surgeon, who will effect the permanent arrest of the hæmorrhage by the measures to be described later.

If the wound is at the root of a limb, in Scarpa's triangle, the axilla or the neck, proximal compression is impossible. Temporary arrest of hæmorrhage under emergency conditions may be effected in two ways: by direct pressure upon the bleeding point, and by the temporary closure of the wound.

Direct compression is effected by thrusting one or more fingers into the wound and closing the vessel. Serious hæmorrhage may easily be arrested in this manner. The drawback to the method is that it practically prevents the transport of the patient. For this reason its chief field of usefulness is at the dressing station while the surgeon is preparing to tie the vessels in the wound. I remember the case of a man, however, who was wounded in the neck by a knife in a public square and fell to the ground bleeding profusely from the internal jugular vein. A doctor who was passing placed his finger on the wound and kept it there until the patient reached the hospital, where I, being on duty at the time, ligatured both ends of the vein. Such a case as this is exceptional, however, and direct compression is more often carried out by means of a compress, a field dressing, or anything at hand that can be pressed into the wound as a dressing. The extemporised pad is secured by a turn of bandage or other means, and then the patient is taken to the surgeon as soon as possible. This method of procedure is, however, attended by certain disadvantages. It is not always efficacious, it may increase the risk of sepsis, and it is not universally applicable. It is particularly inapplicable to certain wounds at the root of the neck, where it is impossible to apply sufficient pressure to arrest the hæmorrhage without

compressing the air-passages. It is in such cases that temporary closure of the wound is indicated.

It will be shown later that in many cases of punctured wounds of large vessels transport for a short distance, say to a dressing station, is perfectly well tolerated. The blood spreads round the vessel and raises and distends the skin; spontaneous hæmostasis takes place, and the patient is able to reach the surgeon. Such being the case, is there no way of transforming an extensive wound from which the blood flows freely into a limited one favourable to spontaneous hæmostasis? I once saw a man brought into the hospital who had been struck in a factory 25 miles away by a splinter of iron which divided the common carotid after making an opening in the skin 2 inches long. A doctor who was on the spot a moment after the accident occurred closed the skin wound with a Kocher's forceps, and the patient was brought to the surgeon without the loss of a drop of blood.

The proper treatment, then, is compression above the wound, compression in the wound, or temporary closure of the wound, and then conveyance to a dressing station without loss of time.

B. At the Ambulance.—The surgeon has two objects in view: first, to secure permanant hæmostasis, and second, to overcome the profound anæmia.

I. PERMANENT HÆMOSTASIS OF A WOUND OF A MAIN VESSEL may be secured by ligature of the vessel, prolonged forci-pressure, or vascular suture.

Ligature.—This operation consists in the application of a firm ligature to both ends of the divided artery. In spite of all that has been said to the contrary, No. 2 catgut is, in my opinion, strong enough for the largest arteries.

The mechanism of permanent hæmostasis is as follows: On tying the ligature tightly, the middle and internal coats are ruptured and retract within the adventitia, their extremities coming together in the form of an actual dome, to adopt Forgue's expression. It is a mistake to tie the ligature loosely. The coats unite by first intention, and there is no need for coagulation (fig. 19).

Fig. 19.—Diagram showing effect of a tightly tied ligature upon an artery.

Union by first intention in this fashion may, however, be interfered with by either sepsis or vascular contusion. However slight may be the sepsis in the region of the vascular wound, and however inconsiderable the lesion extending up the internal coat, the blood coagulates in the ends of the vessel. The clot in the central end projects for a varying distance into the lumen, and may extend up and block an important collateral branch. This is a factor which considerably affects the results of ligature.

To obtain arterial cicatrisation without or with a minimum of thrombosis two conditions are essential: first, that the ligature is and remains aseptic; second, that it is applied to a healthy portion of the vessel.

For the ligature to be and to remain aseptic it must be used in tissues which have been surgically prepared. It is common knowledge that the walls of all war-wounds are contused and devitalised from the beginning. They are infected from the very outset, the germs multiplying not only on the surface of the tissues, but in the depths of the devitalised zone.

Under the influence of the defensive reactions of the body all the dead skin, cellular tissue, muscle and bone forming the walls of the wound become liquefied, detached from the surrounding healthy tissues, and gradually eliminated. The process of elimination is naturally accompanied by an inflammation of varying intensity, ranging from a simple and transient serous discharge to profuse and persistent suppuration. It is not difficult to foresee the result of ligature of an artery at the bottom of a wound such as this.

It is believed by many that suppuration of this kind may be met by opening up the wound and irrigating with bactericidal solutions, such as solutions of hydrogen peroxide, chlorinated soda, carbolic acid, or the hypochlorites. But no one has ever seen a contused wound treated by antiseptic irrigation which granulated and healed up without first passing through the stage of elimination of the dead parts. Irrigation, by its mechanical action, may perhaps hasten the separation of sloughs, but that is all. I am convinced that the sole method of preventing suppuration in war-wounds is immediate surgical intervention. The operation consists in the immediate excision of the contused tissues, swarming as they are with germs and irrevocably condemned to suppuration and eventual death. The cutaneous edges of the wound, the cellular tissue, the débris of muscle and aponeuroses should all be excised; free and adherent splinters of bone should be removed by means of a rugine, leaving a large, clean wound with fresh and bleeding walls, at the bottom of which lies the injured artery. By this means a contused and infected wound is converted into one which is clean and aseptic and the first condition of successful arterial ligature is assured.

The second condition is to apply the ligature to a healthy part of the vessel. It is only by cleaning the contused wound and careful excision of its walls that the whole extent of the injury to the artery becomes visible. By irrigating the wound in the vessel with saline solution the extent of the laceration of the middle coat and of the ruptures of the inner coat within the lumen of the vessel may be plainly seen. If thrombosis is to be avoided, the ligature must be tied well above these injuries, hence the vessel should be treated in a similar manner to the wound; it should be freed from its sheath, and the ligature applied to a sound portion, the subjacent contused portion being cut away. Owing to its elasticity the tied artery retracts up its sheath, and is thus protected from external injury.

By this method an aseptic ligature is effected, which will progress under aseptic conditions, and terminate in cicatrisation of the artery without thrombosis. The conditions are essential to safe and certain ligature, and the case in point is but an illustration of the technique applicable to all war-wounds.

Forci-pressure.—The employment of forci-pressure to obtain permanent arrest of hæmorrhage is in the nature of a makeshift, and is rarely indicated in a recent vascular injury. As we shall have occasion to show later, this does not altogether apply to old and infected wounds, nor to secondary hæmorrhage. In the case of recent injuries, forci-pressure is employed only where ligature is impossible, as, for instance, when an artery is badly torn and very much retracted at the bottom of a wound, the walls of which are inelastic and in which inspection is impossible. I employed it in one case of complete division of the

gluteal where the artery had retracted so far beneath the pelvic arch that isolation was impossible. I also saw it employed in one case of rupture of the popliteal artery with its companion vein, both vessels being clamped together transversely. In both cases permanent arrest of hæmorrhage was obtained.

Suture.—The suture of a vessel is not a difficult matter provided that the vessel has been surgically prepared, that is to say, isolated, dissected out, and, of course, rendered exsanguine by one of the numerous methods of securing temporary arrest of hæmorrhage. Both straight and round needles, according to requirement, are employed. These should be round in section, without cutting edges, and very fine (Kirby's Nos. 15 and 16 are the best). Very fine silk sterilised in vaseline is used for the stitches.

Lateral suture is performed in the following manner. The needle is preferably a straight one, especially when the wound is sufficiently large and gaping to permit of its manipulation. It is held in the right hand, and the first stitch is placed in the angle of the wound nearest the operator. The left index finger supports the vessel close to the wound and holds it well up to the needle (fig. 20). The third or fourth finger of the left hand is employed to tauten the thread after the first stitch has been inserted. The stitches perforate all the coats, and are placed $\frac{1}{12}$ inch apart along the entire length of the wound as a continuous suture. To ascertain whether there is leakage from the line of suture the blood is allowed to flow into the vessel. If a minute drop of blood appears between two stitches, an additional stitch should be added at that point.

Theoretically, the method is applicable to incomplete rupture and to a perforation of the artery.

In making a circular suture the first step is to put two or three guiding threads (Carrel) at equal distances apart around the circumference of the central end;

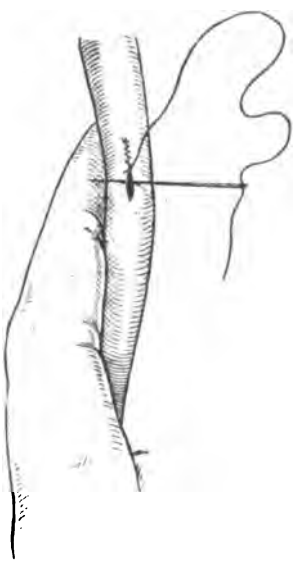

FIG. 20.—Diagram showing lateral suture of an artery.

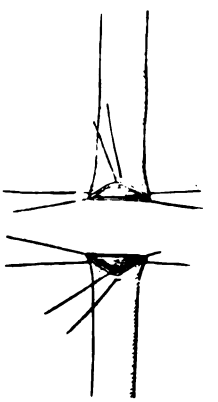

FIG. 21.—Diagram showing circular suture of an artery. First stage: application of the guiding threads.

these are then passed through the corresponding points in the peripheral end (fig. 21). When drawn tight these threads bring the two ends of the vessel together, giving the section a triangular form. By pulling lightly upon two of these threads the assistant presents a transverse wound to the surgeon, who unites the edges with a continuous suture with the stitches close together. The same is done upon the remaining sides of the triangle (figs. 22, 23). The

ıpermeability of the suture is tested by restoring the rculation in the vessel; where necessary, supplementary stitches are inserted.

Theoretically, the method is applicable to complete ction and to complete rupture of the vessel.

Associated with circular suture is the *vascular*

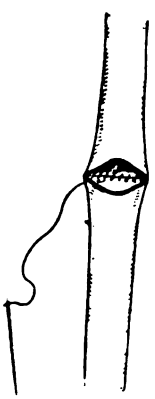

FIG. 22.—Diagram showing circular suture of an artery. Second stage: commencement of the running suture.

FIG 23.—Diagram showing circular suture of an artery. The circular running suture is nearly finished.

ıft. Although arterio-arterial and peritoneal grafts ve been proposed and even performed, it is an doubted fact that the arterio-venous graft is the e grafting method which is really practicable in man surgery.

The graft may be obtained from the accompanying ın or from one in the opposite limb. The great vantage of the former method lies in the fact that egment which preserves connection with its sheath, branches, and the tissues surrounding it, presents

all the requisite conditions of viability. I believe that this is far the better method, for the risk attaching to ligature of the vein is infinitely less than the disadvantages inevitable to the transport from a distance of a complete graft from the opposite limb.

Theoretically, vascular transplantation is applicable to cases where the loss of vascular substance is too extensive to be amenable to circular suture.

Thus, apart from forci-pressure, which must be regarded as a method of necessity, there are two principal methods of obtaining permanent hæmostasis. How is the choice between these methods to be made?

Choice of a method of effecting permanent hæmostasis.—Ligature of a wounded vessel has long been regarded as a simple, easy, and efficacious operation. Its fundamental advantages lie in its simplicity and its security. It is not necessary to enlarge here upon the simplicity of the operation, and its security is equally well established. Former experience in this direction is abundantly confirmed by results obtained in war-wounds. The danger of the method lies, however, in the risk of abrupt suppression of the circulation in the area supplied by the vessel, with consequent gangrene of the limb.

Is this danger as great as it was commonly believed to be before the war? Statistics published before 1914 show that the average incidence of gangrene was as follows:—

After ligature of the			subclavian,	in	5	per cent. of cases.
,,	,,	,,	axillary,	,,	15	,, ,,
,,	,,	,,	brachial,	,,	5	,, ,,
,,	,,	,,	common iliac,	,,	50	,, ,,
,,	,,	,,	common femoral.	,,	25	,, ,,
,,	,,	,,	popliteal,	,,	15	,, ,,

Thus, although comparatively rare in the case of the upper limbs, its incidence was extremely frequent in the lower ones. These figures must not, however, be taken as representative of ligature in recent vascular wounds, for they include also the figures for ligature in diffuse arterial hæmatoma and in aneurism. On the other hand, it may be urged that gunshot-wounds are more liable to gangrene than those of any other class. Such wounds are almost invariably contused, and they are associated with extensive laceration, and with contusion of the collaterals and of neighbouring veins and nerves. The ischæmia provoked by the application of a tourniquet, the vasomotor disturbances due to irritation of the collateral vessels, and the contusion of the peri-arterial sympathetic nerve-plexuses are all factors that inevitably predispose to ischæmic gangrene of the limb. Yet, in spite of all this, gangrene after ligature of a recently wounded artery is exceptional.

Out of a large number of cases in which the axillary, femoral, or popliteal vessels were ligatured within a few hours of injury I have seen only two instances of gangrene—one after ligature of the common femoral, and one of the popliteal. As a matter of actual fact, the circulation after ligature is rapidly re-established by way of the collateral vessels, and, at the end of three or four days, the pulse (radial or pedal) reappears. This shows very clearly that, in the vast majority of cases, simple ligature of a large artery is not in itself sufficient to provoke gangrene.

The true causes of gangrene after ligature are those that impede the establishment of the collateral circulation. Such are vascular thrombosis, reaching from the ligature to the collaterals above, and

peri-arterial hæmatoma, which compresses the collaterals above and below the wound. Now in the class of large wound at present under consideration arterial hæmatoma does not occur. And if the wound in general, and the vascular wound in particular, be treated surgically in the manner described above, thrombosis, which is the outcome of arterial contusion and infection, will also not occur. As I shall show later, this does not altogether apply to ligature for arterial hæmatoma, where the collateral vessels, owing to compression by the effused blood, are definitely paralysed and, even after evacuation of the hæmatoma, are unable to assure the circulation of the limb. I have notes of seventy cases of ligature of main arteries where the vessels were tied within a few hours of the injury and no hæmatoma of any size was present. The position of the ligatures was as follows :—

Common carotid	1	External iliac	1
External carotid	1	Femoral	11
Internal jugular vein	2	Gluteal	2
Axillary	10	Popliteal	6
Brachial	5	Popliteal vein	2
Ulnar	7	Anterior tibial	4
Radial	10	Posterior tibial	8

Ischæmic gangrene occurred only twice, once after ligature of the femoral and once after ligature of the popliteal.

A contrast is provided by the histories of forty-two cases of diffuse arterial hæmatoma in which a main artery was ligatured. Including those cases only in which the ligature was applied to the dangerous arteries, namely, the axillary, femoral, and popliteal, gangrene occurred in the following proportion : axil-

lary, two in five; femoral, two in ten; popliteal, two in five.

It is evident, then, that ligature of a sound portion of an arterial trunk in a large wound which has been surgically prepared is accompanied by only slight risk of ischæmic gangrene. Ligature is a simple operation which does not endanger the life of the patient, and it appears to be almost equally free from danger to the limb.

Vascular suture is in theory the ideal method, for it assures arrest of hæmorrhage, while preserving the lumen of the vessel intact.

Restitutio ad integrum after suture of a vascular wound depends on two conditions: the aseptic course of the suture, and the absence in the neighbourhood of the suture of lesions likely to provoke thrombosis.

Asepsis is as essential to the success of arterial suture as it is to ligature. The method of surgical disinfection of the wound by early and careful excision was described in a previous paragraph, and there is no reason why the site should not be prepared for suture in the same way as for ligature. It is incomprehensible that so many surgeons should condemn vascular suture in wounds of war simply because these wounds are septic wounds. When a suture is efficiently performed, and there is no leakage from the suture line, there is no reason why it should be more exposed to infection than a ligature or, for that matter, a normal artery which has been isolated and denuded in the wound. The disinfection of the wound lies entirely in the hands of the surgeon, and it is invariably obtained by efficient excision.

Contusions of the intima offer a serious obstacle to

the normal progress of arterial suture. To suture a lateral wound, or to unite the two ends of a divided artery without taking such lesions into account, is to court disaster. A thrombus forms, the artery is obliterated, and the entire *raison d'être* of the suture is lost. Or, worse still, gangrene may be provoked by emboli from the thrombus, when the suture becomes a positive source of danger.

In the case of a lateral wound the edges should be cut away until all trace of the laceration of the internal coat is lost. It follows that, in many cases, the wound exceeds one-half of the diameter of the vessel and is no longer amenable to lateral suture, but must be treated by resection and circular suture. Under these circumstances the indications for lateral suture become very much reduced.

Where rupture is complete, the two ends of the vessel must also be cut away until the external and internal lacerations disappear and the two surfaces are absolutely clean-cut. Here, again, the limits within which a loss of arterial substance is reparable by circular suture are very soon passed. It is generally conceded that a loss of an inch and a half is the extreme limit within which circular suture is permissible. By keeping the limb in a special position it is undoubtedly possible to facilitate the coaptation of the ends of the vessel, and the vessel may be mobilised by liberation at a distance after ligature and section of the first collaterals, but these are merely expedients. When the loss of the wall reaches the limit above mentioned, circular suture becomes impossible.

In such a case, is vascular transplantation indicated? This operation is successful only where the graft is

protected from external injury from the very outset, and where its walls are enabled rapidly to form adhesions with the tissues which surround and preserve it. Thus the method is not applicable to wounds which must be kept open.

It is evident from the details contained in the preceding paragraphs that, owing to the specific anatomical conditions incidental to war-wounds, arterial suture is in general a long and complex operation, which is assured of success only when preceded by extensive excision of the wound. This explains why the number of arterial sutures done since the beginning of the war is very limited. On the one hand, we have in ligature a simple, easy, and certain method which is almost entirely free from danger; on the other. in arterial suture a long and tedious operation, leading at great cost to precisely similar results. No wonder the decision is in favour of ligature?

Should suture then be absolutely excluded? As a matter of fact, it should not. The indications are best arrived at in the following manner:—

The wound is well opened up, excised and cleansed. Hæmorrhage is arrested by pressure above, and the condition of the arterial wound is carefully examined. Where laceration is extensive, or where there is complete rupture, with or without loss of substance, each end of the artery should be ligatured in the wound. Where there is a slight lateral wound, such as may be caused by a small fragment of shell or grenade, the choice lies between section of the vessel with ligature of both ends, and lateral suture. Is it expedient to sacrifice an artery especially a dangerous artery which is only slightly wounded,

by cutting and tying it? In such a case the edges of the wound should be caught with fine forceps and everted, the artery emptied by washing it out with a little saline solution, and the damage then examined at leisure. If the lesions are very limited, and there is no laceration of the intima, lateral suture may be safely undertaken. Where the conditions are the reverse of these, the vessel should be divided and each end tied. The conclusions to be drawn then are: that ligature of the vessel is the method *par excellence* for the arrest of hæmorrhage from recent vascular wounds, and that indications for suture are exceptional.

II. Treatment of Acute Anæmia.—The surgical measures for assuring permanent arrest of hæmorrhage are reinforced by measures intended to overcome the profound anæmia arising from loss of blood.

In addition to the minor measures enumerated below, there are two principal methods of treating the condition, namely, by injection of artificial (physiological) serum, and by transfusion of blood.

The minor measures, all of which are valuable aids to treatment, include warmth; bandaging the limbs over a wool compress; inclination of the body with the head low; oxygen inhalations; hypodermic injections of ether, camphorated oil, or strychnine. It is most essential that the patient should be kept warm, even in summer, especially towards night or daybreak, and after lying on the ground during the early part of the night. The constant, warm temperature of the operating theatres in the motor-ambulances marked a great advance in this direction. The individual heating of the patient by one of the numerous

devices introduced during the last two years is a valuable auxiliary measure. The simplest method is to enclose the patient, exclusive of the head, in a kind of cage, under which a portable heater is introduced (fig. 24).

Injection of physiological serum.—Of all the methods employed to reduce the profound anæmia which accompanies large wounds of war, this is the simplest,

FIG. 24.—J. Poucel's hot-air stretcher apparatus.

the most widespread, and, after transfusion of blood, the most efficacious. The serum most commonly employed is Hayem's serum, a solution of 7 per 1000 of common salt. J. Gautrelet, however, whose experience is based on numerous physiological experiments, has replaced it with a formula of Locke's. Locke's preparation represents the only true physiological serum in the sense, that it is the only fluid which is "entirely able to fulfil the functions of the circulating blood, and, unaided, to assure and to re-establish normal organic function, notably that of the heart."

Its composition is as follows:—

Sodium chloride	8 gm.
Calcium chloride	0 gm. 20
Potassium chloride	0 gm. 20
Bicarbonate of soda	0 gm. 20
Glucose	1 gm.
Distilled water	1000 c.cm.

It is prepared by simple solution of the ingredients and filtration. It is sterilised by boiling or in an autoclave, and is readily prepared at any dressing station. It is not proposed to enter here into the purely physiological advantages which render this preparation superior to Hayem's serum. These have been categorically defined by Gautrelet. For my own part, I have used at least 20 litres (704 oz.) of Locke's serum at the front, and, although I have no sphygmographic records of the intensity and rapidity of its action in comparison with that of Hayem's serum, I am firmly convinced that it is a most efficacious and reliable medium. I have no hesitation in recommending its employment.

Injection is performed either hypodermically or intravenously. In grave hæmorrhage, such as that now under consideration, it should be performed intravenously whenever possible.

The most suitable site is either one of the superficial veins at the bend of the elbow, or the internal saphena immediately in front of the internal malleolus. When transfusion is carried out during operation the latter site is preferable, as the manipulation is less hampering to the surgeon.

The classical technique of intravenous injection consists in pricking the skin immediately over a vein

and at once puncturing the vein. The method is, however, not applicable here. Owing to the extreme hæmorrhage the veins are empty and relaxed, and are barely visible. To attempt the puncture of such a vein is usually to miss it, and to succeed in pricking it is, more often than not, to traverse it. It is very rare indeed for the needle to be correctly placed at the first attempt. It has been affirmed that to puncture a vein accurately it is sufficient to prick the skin on one side of the vein and to force the point of the needle sideways until it penetrates the vessel wall. The method is undoubtedly a good one.

FIG. 25.—Canula for intravenous transfusion of serum. (Willems.)

Nevertheless, to puncture a vein quickly, unhesitatingly, and successfully, by far the best method is to make an incision half an inch long in the skin over the vein, isolate the vessel by a stroke of a director, and to insert the needle when one can see clearly what one is doing. Some surgeons prefer a needle with a short bevel, some a needle with a long one. It is very difficult to obtain good needles of a large size which are well adapted to the injection. According to Willems, English surgeons employ a curved canula (fig. 25) 2 mm. in diameter, with a blunt, bevelled point, which is introduced into the vein after it has been exposed and incised. The calibre of the canula permits of the injection of 1–1½ litres (35–52 oz.) of the solution in a few minutes. There is no doubt that the instrument is an excellent one.

The immediate result of transfusion is to diminish or to abolish the most marked of the anæmic symptoms. The lips and conjunctivæ recover their colour, the general pallor decreases, the pupils contract, and there is a subjective sensation of well-being. If the blood-pressure is taken on the patient's arrival, and again after the transfusion of 1000–1500 gm. (35–52 oz.) of serum, a considerable rise will be observed. I have at this moment before me the tracings obtained at my ambulance by my colleague, Joussemet. The maximal pressure, by Vaquès' instrument, rose from 8 to 12, 10 to 15, 9 to 15, 0 to 8, etc. The minimal pressure rose from 6 to 8, 6 to 10, 0 to 10, 6 to 9, etc. The significance of these figures lies in the fact that where the blood-pressure rises steadily and the rise is maintained hæmorrhage is the main factor, if not the only one, in the production of the hypotension, and the prognosis is in consequence favourable. But where, in spite of transfusion, the pressure either does not rise, rises very little, or rises only to fall again immediately, the inference is certain that the hæmorrhage is not the fundamental cause of the hypotension and of the clinical signs which accompany it. In cases such as these the result is referable to the sympathetic reaction so characteristic of traumatic shock. This aspect of the matter will be more fully dealt with in a later chapter. For the moment it is sufficient to emphasise the fact that if after transfusion of serum the blood-pressure rises steadily and rapidly the prognosis is favourable, and the patient will recover.

Transfusion of blood consists in passing into the circulation of the exsanguine patient a more or less considerable quantity of blood taken from a healthy

subject. I shall not enumerate all the ways in which this may be done, but shall confine myself to two methods of which I have had personal experience—direct transfusion by means of Elsberg's canula, and indirect by means of sterile paraffined tubes.

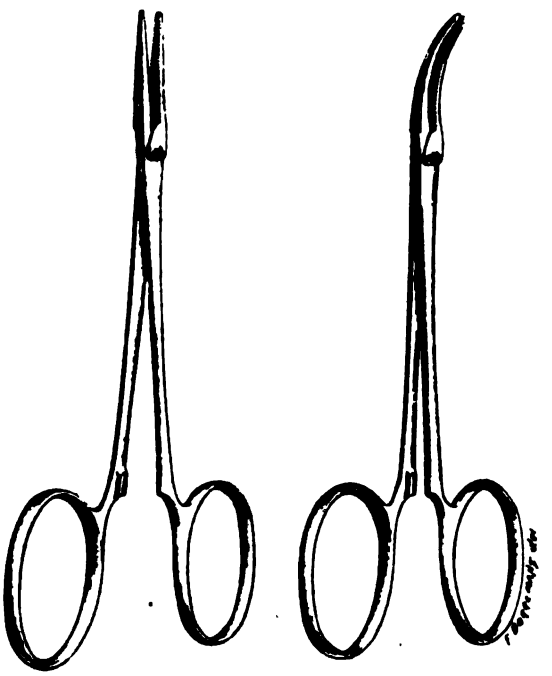

FIG. 26.—Halsted's forceps for delicate dissection work and ligature of small vessels.

Direct transfusion by means of Elsberg's canula.—The patient, the recipient, is laid horizontally on the operating table, and the healthy subject, the donor, lies on another table of the same height parallel to the first. These two tables are arranged so that the right arm of the donor and the left arm of the recipient lie alongside each other and perfectly parallel on a small table placed between the two operating tables.

The operation consists in anastomosing the radial artery of the donor with the basilic or cephalic vein of the recipient by the intervention of Elsberg's canula. Both limbs are stretched at full length, painted with tincture of iodine, and enclosed in sterilised towels. Novocaine is used as a local anæsthetic for both donor and recipient, the artery being first injected with 10 c.cm. of a 1 per cent. solution of novocaine. The same solution is injected in the

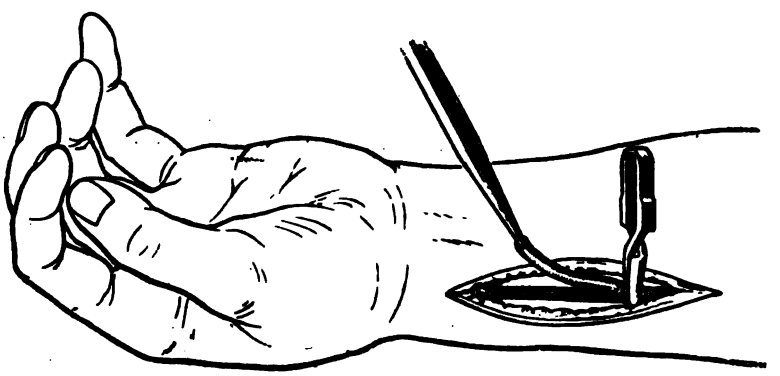

FIG. 27.—Transfusion of blood. Preparation of the radial artery of the donor.

neighbourhood of the vein of the recipient after a bandage has been placed round the limb higher up, to be tightened when the vein has to be exposed.

An incision 2 inches long is made along the line of the pulse, exposing the radial. This is separated from its sheath by means of a director, which involves the ligature of three or four very small collateral branches which the artery gives off at this level. To secure these arterioles Halsted's slender forceps (fig. 26) are employed, and the vessels are tied with very fine catgut. Near the upper end of the incision the artery is clamped with a special artery-clamp

with parallel blades, ligatured as near the lower end as possible, and divided immediately above the ligature. This gives a free segment of the artery about 2 inches long (fig. 27).

Elsberg's canula (fig. 28) is then placed on the radial. This instrument is in the form of two metal half-cylinders, the concavities of which face each other, and which may be separated or approximated by a screw on the handle. On the external surface of each half-cylinder are two little curved hooks pointing away from the tip of the cylinder. The

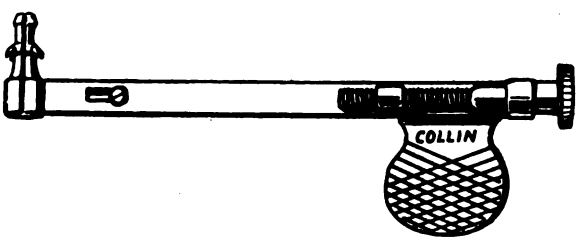

FIG. 28.—Elsberg's canula.

freed artery is placed between the two halves of the cylinder in such a way that its cut end protrudes a third of an inch beyond the tip of the canula. The two parts are then screwed together until they exactly touch the vessel walls. The free end of the vessel is then seized with fine forceps and split with a fine bistoury introduced into the lumen along $\frac{1}{6}$ inch of its length (fig. 29). Then, while the canula is steadied by an assistant, the edges of the split portion are seized with two pairs of fine forceps, such as are used in ophthalmic work, and the segment turned back until it can be caught by the little hooks (fig. 30). Dehelly points out, with justice, that this manœuvre is difficult if the split portion is too far from the end

of the canula; $\frac{1}{8}$ inch, no more and no less, of the artery is left intact beyond the tip of the canula.

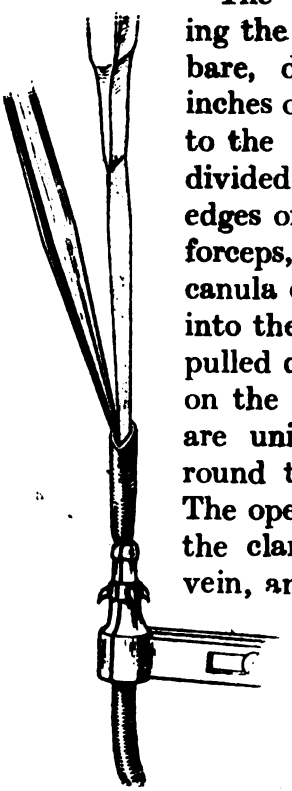

Fig. 29. — The segment of the artery which protrudes beyond the canula is split with the bistoury. (Guillot and Dehelly.)

The vein, rendered visible by tightening the constricting bandage, is now laid bare, dissected out, and freed for 3 inches of its length; a ligature is applied to the peripheral point, and it is there divided. The assistant then grasps the edges of the divided vein with two fine forceps, and the operator coaxes the canula covered with the inverted artery into the lumen of the vein. The vein is pulled down over the artery and caught on the little hooks, and the two vessels are united more firmly by a ligature round the base of the hooks (fig. 31). The operation is completed by removing the clamp forceps from the artery and vein, and by slightly separating the two sides of the cylinder by means of the screw so that the lumen of the artery is quite free. The blood passes directly from the artery into the vein, which is seen to pulsate, while the assistant keeps the two limbs in contact, and the operator keeps the vessels moist by sprinkling them with warm artificial serum.

Indirect transfusion by means of tubes sterilised in paraffin (Carrel's method modified by Bérard).—When the artery has been completely isolated in the radial groove a lateral incision, not exceeding half the circum-

ference of the vessel, is made with very fine scissors, and into this a Carrel's tube is introduced. Carrel's tubes are slender tubes of silver $\frac{1}{8}$ mm. in thickness, bent in the form of an elongated S, and ending in small bulbous enlargements meant to retain ligatures. These canulæ are sterilised in a paraffin mixture, and are kept in glass tubes like those for catgut (Daufresne). The tube is grasped by special forceps and inserted into the opening in the artery, a ligature below the bulbous enlargement fixing it in place. The artery is now ready (fig. 32).

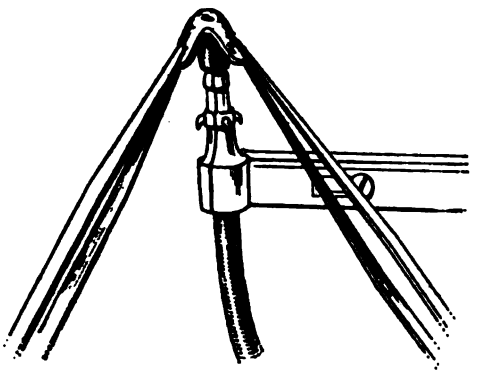

FIG. 30.—The split artery is turned back on the canula. (Guillot and Dehelly.)

The vein of the recipient is next prepared, the arm of the donor is then placed in such a way that the end of the canula is touching the segment of vein

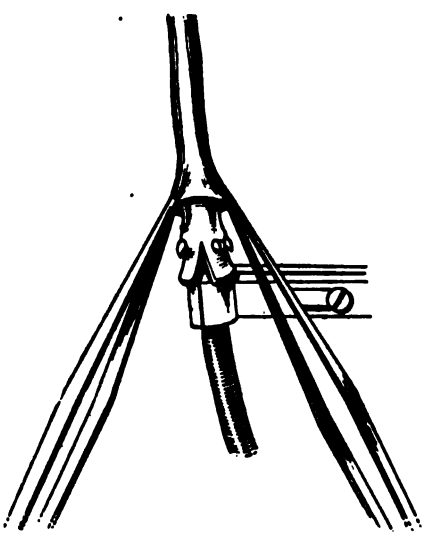

FIG. 31.—The canula, capped with the artery, is introduced into the vein. (Guillot and Dehelly.)

prepared for it, and a snip is made in the vein similar to that in the artery. Before inserting the canula into the vein the arterial clamp is loosened in order to expel any air that may be present, and the canula is then slipped quickly into the vein and secured by a ligature. Both artery-clamps are now removed, and transfusion is established.

Whichever mode is employed, transfusion is

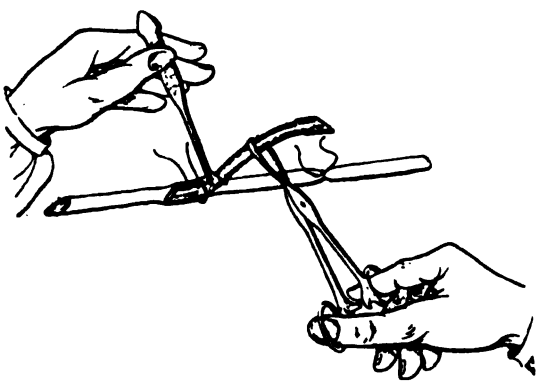

FIG. 32.—Introduction of the transfusion canula into the artery. (Bérard and Lumière.)

arrested either when the donor shows the first signs of anæmia, such as vertigo, thirst, sweating, etc., or when the main anæmic symptoms disappear in the recipient, when the mucous membranes resume their colour, the limbs become warm, and the pulse perceptible.

Transfusion of blood is an operation of unquestioned efficacy. All who have employed it have had unhoped-for success with it, and I have myself, thanks to it, seen a surprising case which might be called a resurrection. Nevertheless, there are those who object to it, some declaring it to be useless if not dangerous.

I do not propose to enter upon such a discussion, or to inquire into the respective merits of intravenous injection of serum and transfusion of blood. The intravenous injection of physiological serum which fills up the vascular system and raises the blood pressure is an excellent method of treating anæmia. Its simplicity, rapidity, and efficacy make it the best method for everyday use. Transfusion of blood is, in theory, the ideal method of treating profound anæmia. Not only does it fill the vascular system and raise the blood-pressure, but it introduces the corpuscular elements into the body and causes a living fluid, containing all the indispensable internal secretions, to circulate through it. The length of time required for the execution of the method renders it, however, unsuitable for general employment, especially under war conditions.

2. *Punctured Wounds*

SYMPTOMS, DIAGNOSIS, AND CLINICAL COURSE

This group includes penetrating bullet-wounds with punctiform skin wounds, and penetrating or perforating wounds produced either by a shrapnel-ball, or a fragment of shell, grenade, or torpedo. In the first case, the orifices of entrance and exit are punctiform; in the second, the orifices are not punctiform, but the wound is characteristically narrow, and is almost entirely closed, either by the missile itself, by débris of all kinds, or by the absence of parallelism between the lesions of subjacent anatomical planes.

If, in such a wound, a large vessel is ruptured the results may be as follows :—

1. The situation of the damaged area may be such that the vascular wound is in open communication with a cavity, either splanchnic, pleural, or peritoneal. From the moment of injury the blood is effused into the serous cavity, and internal hæmorrhage results.

2. The situation of the damaged area may be such that the gaping vascular wound is not in communication either with a serous cavity or with the exterior. The blood is effused into the damaged area and the tissues surrounding it, and a diffuse hæmatoma results.

3. The situation of the vascular wound and its relationship with the surrounding tissues may be such that only slight interstitial hæmorrhage takes place. Here we have a vascular wound without hæmorrhage.

1. Internal Hæmorrhage

Internal hæmorrhage occurs in association with penetrating wounds of the thorax and abdomen. A large parietal or splanchnic vessel in the pleura or peritoneum has been opened and the blood escapes freely into the serous cavity.

In the majority of cases death follows with extreme rapidity. In the case of rupture of a large mediastinal vessel (aorta, vena cava, pulmonary vein) or of a large abdominal vessel (abdominal aorta or vena cava, renal vessels, cœlic axis), death is inevitable. The wounded man dies on the spot a few moments after the injury has been received, before a doctor can be summoned to his aid.

I have, however, observed one exceptional case. I operated two hours after the injury upon a man who had been wounded in the precordial region by a shot

from a revolver. He presented all the signs of a cardiac wound, and, as a matter of fact, I found the orifice of entry in the anterior wall of the left ventricle. Having sutured the wound, I found the orifice of exit in the posterior wall of the same ventricle, in the auriculo-ventricular furrow. I sutured it, and closed the pericardium without having discovered the missile. The patient lived from eight in the morning until five in the evening. The autopsy showed that the ball had passed through the descending portion of the aortic arch, around which an enormous mediastinal hæmatoma had formed.

In other cases death is delayed for several hours, or even for several days. It is not inevitable, and may be averted by appropriate treatment. This applies particularly to penetrating wounds of the thorax, with lesion of the parietal vessels or of the pulmonary vessels of the second order. More frequently the conditions arise in association with penetrating wounds of the abdomen, with lesion of the parietal or splanchnic vessels (gastric, gastro-duodenal, splenic, mesenteric, colic).

In these cases, as sometimes happens in external hæmorrhage, emotion, such as pain or fear, combines with the rapid lowering of the blood-pressure to produce syncope. The patient loses consciousness, the flow of blood diminishes, and finally ceases. I have shown in an earlier chapter that complete rupture is more favourable to spontaneous arrest of hæmorrhage than is partial division, and that it is more frequent in association with contused and lacerated wounds than with a clean-cut section. But in the cases under consideration, especially those of pleural hæmorrhage, spontaneous arrest is facilitated

by certain contributory causes. The first of these is intra-pleural pressure, which tends to increase until it equals that within the vessel. The second is the retraction of the pulmonary parenchyma, the tissue contracting upon itself until it finally obliterates the lumen of the injured vessel.

A patient who is brought to the ambulance a few hours after injury with a thoracic or abdominal wound accompanied by internal hæmorrhage presents a complex of general and local symptoms the diagnostic significance of which is unmistakable.

The general signs are those of profound anæmia. The patient is extremely pale; the face is waxen, and covered with sweat; the mucosa are blanched; the voice is weak and broken; the pulse is small, almost imperceptible, and very rapid. While he is being warmed the patient presents signs of extreme anguish; he is restless, sighs deeply, repeatedly sits up in bed only to fall back exhausted on the pillows. Do these striking general symptoms point to grave internal hæmorrhage?

This clinical picture, which is portrayed only in broad outline, is observed in a large number of cases, but it is not always referable to the same causes.

It sometimes happens that the patient is wounded in many places; a first glance shows that the arms, legs, trunk are riddled with wounds. Closer examination reveals the fact that a leg, a forearm, perhaps several segments of a limb, are fractured, yet moving them does not provoke either pain or protest.

In other cases two or three very extensive wounds of the trunk or limbs are discovered, vast lacerated areas situated in the back, the buttocks, the roots of the thighs, produced by violent explosion or by

secondary missiles, such as pieces of wood or iron blown off from objects in the neighbourhood of the wounded man. The rents in the skin reveal the torn and broken muscles beneath covered with dirt, portions of clothing and mud, and closer inspection of this formidable traumatic area shows that the tissues are dead.

In both cases no important viscera have been injured, and there is in fact no great amount of hæmorrhage, either external or internal, no *a priori* cause for the gravity of the symptoms. This is the condition commonly known as *traumatic shock.*

Generally speaking, traumatic shock is characterised by an abnormal and profound lowering of the blood-pressure. Extensive hæmorrhage, whether external or internal, inevitably produces rapid and extreme hypotension. It is certain, however, that there must be other determining causes, for the condition is observed, as in the cases under discussion, where hæmorrhage is comparatively slight.

There is no doubt that traumatic shock arises from a complexity of causes. Among the etiological factors we must include general nervous exhaustion, due to multiple stimulation of peripheral nerves; sympathetic vasomotor reaction, produced by multiple wounds; and general toxæmia, due to rapid death of bruised and lacerated tissues and the absorption from large surfaces of the products of tissue destruction caused by wounds.

However that may be, is traumatic shock distinguishable from acute anæmia? Or rather, when faced with the serious symptoms which I have described is it possible to define how far they are due to hæmorrhage or to other causative factors, namely, toxæmia

and nervous shock? It has certainly been said that in anæmia the pallor is greater, the colour more waxen, and the nails whiter; in shock, on the other hand, the fulness of the veins causes cyanosis of the face, the hands, and the nails. In anæmia, too, the "air hunger" and restlessness are said to be more marked; and in shock, general insensibility and anæsthesia are more profound. But these are really only shades of difference, and it is often very difficult to say *a priori* whether a patient is suffering from anæmia or from shock. More often than not, if the wound is thoracic or abdominal he may be suffering from both.

The condition of arterial tension provides valuable information on this point. A patient is brought to the dressing station pale and pulseless with one or more abdominal wounds. The maximum arterial tension, measured by Vacquès' instrument, is eight, the minimum four. Immediately, and before doing anything else, whilst a laparotomy is being prepared for, he should be given an intravenous injection of 1500 c.cm. of adrenalinated physiological serum. If the arterial tension, taken a few minutes later, has risen quickly and well, and the mucosa and the face show a little more colour, the condition is largely due to acute anæmia. If, however, the tension remains low, or rises very little and falls quickly to its former level, the symptoms are attributable to a cause or causes other than anæmia. The prognosis is favourable in the first case, unfavourable in the second.

The local signs of internal hæmorrhage are those of intra-thoracic or intra-abdominal fluid. Thoracic dulness with disappearance of the vesicular murmur occurring immediately after a chest wound can be due only to hæmothorax; and abnormal dulness in

the flanks, shortly after an abdominal wound, must be due to internal hæmorrhage. Gastro-intestinal bleeding occurs more slowly and is less profuse.

If left alone, these patients almost certainly die rapidly from continued or recurring hæmorrhage. Undoubtedly wounds of the thorax with pleural hæmorrhage which go on to recovery are frequently seen. Immediately after the wound has been received a very abundant hæmothorax occurs, sometimes so great as to displace the heart and depress the liver; then the hæmorrhage may be arrested, the effusion may cease to increase, and the patient picks up and begins to recover. This is due to the fact that the vessels involved in the pulmonary wound are the arterioles and the small veins, not one of the large mediastinal vessels, for in the latter case hæmostasis would not be likely to occur. It is even more improbable in the case of injury to a large vessel near the thorax, such as the subclavian artery or vein. I operated once on a young soldier who had a shell-splinter-wound in the clavicular region, involving the subclavian vein and the dome of the pleura. Although the pleura was full of blood, the vein continued to bleed, and blood escaped from the external wound with each respiration.

In intra-peritoneal hæmorrhage the likelihood of spontaneous arrest is very much less than in a pleural hæmorrhage; the bleeding continues, and without operation death is inevitable.

2. Diffuse Hæmatoma

Diffuse hæmatoma is associated with perforating or penetrating wounds by bullets or splinters. When

the artery is wounded the blood escapes into and around the vascular sheath, into the cellular tissue and between the muscles, and, being unable to escape externally, forms what I have already called a diffuse arterial hæmatoma.

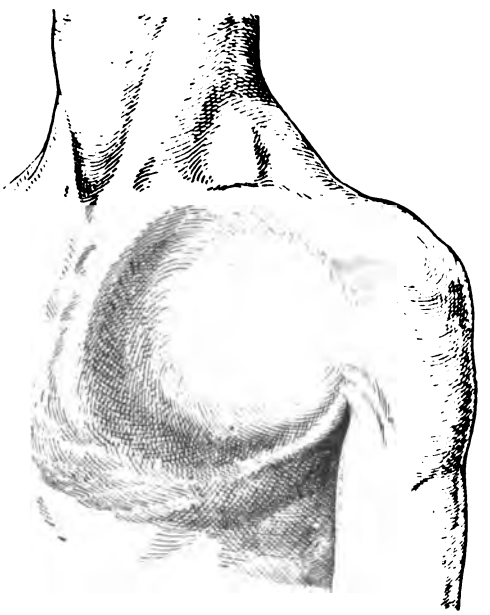

Fig. 33.—Arterial hæmatoma of the axilla. (Author's case.)

I have already shown that, in the case of a bullet-wound with punctiform orifices and an insignificant track, the hæmatoma will form slowly and progressively, rarely attaining any great size; whereas a shell-splinter, which produces a non-punctiform orifice and has a well-marked track, gives rise to a rapidly increasing hæmatoma, which may attain enormous dimensions. These forms of hæmatoma may be regarded as typical, and will be described in turn. Between them lies a range of intermediate forms.

Extensive hæmatoma, developing rapidly.—When a man is brought to the dressing station some hours after being wounded with a very large diffuse hæmatoma, he presents a combination of local symptoms which allows the diagnosis to be made at a glance.

The most noticeable symptom is marked swelling of the wounded limb, which differs in character according to whether the hæmatoma is superficial or deep. *A superficial hæmatoma*, such as that accompanying a wound of the axillary or superficial femoral vessels, presents considerable swelling, which raises the skin of the injured area and forms a tumour of varying

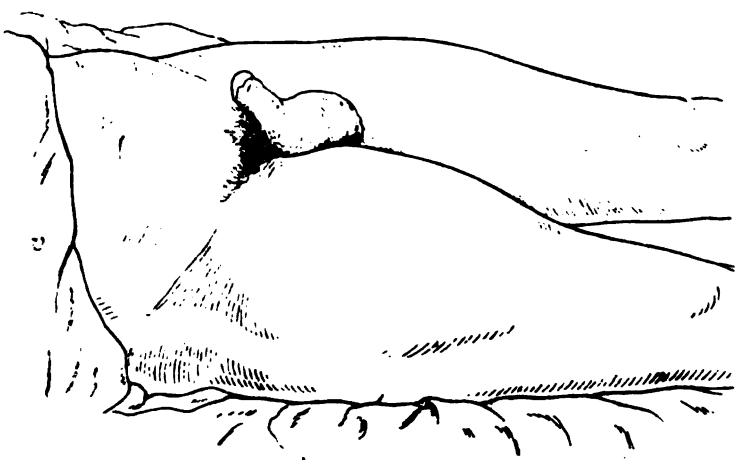

Fig. 34.—Diffuse hæmatoma of Scarpa's triangle. (Author's case.)

dimensions and vague outline. It is, however, a true definable tumour, distinct to both sight and touch. An axillary hæmatoma which elevates the anterior wall of the axilla is shown in fig. 33. Fig. 34 shows a hæmatoma of the common femoral filling up Scarpa's triangle.

Sometimes the swelling appears to be bi-lobed. In the thigh, for instance, the principal mass may be situated in front of the adductors, while a second mass appears behind them.

In the case of *a deep hæmatoma*, such as may follow a wound of the popliteal or the posterior tibial,

the swelling of the limb is general. There is no local tumefaction; there is a general increase in the size of the limb, which looks as if its cutaneous envelope were too tight for the tissues which it contains. In a superficial hæmatoma there is rapid occurrence of an extensive ecchymosis. In an axillary hæmatoma, for instance, this may extend over the lateral surface of the thorax, the back, and the lumbar region as far as the iliac crest. In a deep hæmatoma there is no ecchymosis.

Whether the hæmatoma be superficial or deep, the whole limb is altered in shape, in general appearance, and in colour. It is more or less swelled and œdematous, the skin is pale, yellowish, distended, and cold, and the peripheral pulse is imperceptible. In the region of the superficial swelling or of the most distended part of the limb palpation reveals a diffused puffiness, suggestive of fluid infiltration, but not true fluctuation. On applying the flat of the hand to the swelling, expansile movements may be felt synchronous with the cardiac pulsations, and this movement of expansion is absolutely pathognomonic. Unfortunately it is not a constant sign, or at least it is often very difficult to detect.

Upon auscultation an intermittent murmur is generally apparent, which is synchronous with the pulse, and is due to the passage of the blood impelled by the systolic wave through the arterial wound, the edges of which vibrate as it passes. This murmur is never present except in lateral wounds and incomplete sections of vessels. We know, however, that it is in association with such wounds as these, in which spontaneous hæmostasis is rare, that a large diffuse hæmatoma is observed. For the first few

days the murmur is loud, harsh and shrill, becoming softer and deeper as the lips of the arterial wound become gradually thickened. The murmur is continued along the proximal portion of the vessel, but not for any great distance. In certain circumstances these stethoscopic signs are of considerable diagnostic value. In the case of a wound of the posterior tibial, for example, an intermittent murmur may be the sole sign of the actual cause of a diffuse swelling of the calf.

The symptoms, then, of a diffuse arterial hæmatoma are: localised swelling or diffuse distension of the entire limb, with expansile movements and an intermittent murmur; pallor and coldness of the limb, with suppression of the peripheral pulse.

Small or medium-sized hæmatoma, developing slowly.—The characteristics of a peri-arterial hæmatoma are usually less clearly defined. In the type which has been described, the invasion of the cellular tissues is sudden and rapid, producing in a few minutes, or at most a few hours, either an enormous swelling by which the skin is raised and distended, or a very considerable distension of the entire limb. In the case of the peri-arterial hæmatoma, on the other hand, the effusion of blood may encounter certain obstacles by which its course, and the consequent growth of the hæmatoma, is checked. Bullet-wounds with a narrow track favour this early limitation of hæmorrhage. Certain shell-splinter injuries with severe contusion involve early arterial thrombosis, by which the hæmorrhage is arrested. Consequently, instead of a large, rapidly-forming hæmatoma, such as I have described, we have a smaller and more insidious hæmatoma, the *a priori* diagnosis of which is not

evident. Some localised swelling and a certain amount of distension are present, but then how frequently these symptoms are observed apart from arterial injury!

A venous hæmatoma, or the simple effusion of blood which follows any wound, may cause swelling of the injured part if the escape of blood externally be even slightly hindered. Even where there is no vascular lesion this hæmatoma may be copious, especially if the tourniquet applied at the first dressing station has been applied too loosely, and thus has favoured slight venous hæmorrhage. Below the swelling the limb is pale; it is often cold, and the peripheral pulse is imperceptible. I would draw attention to the fact that patients reach the dressing station seriously chilled, with both lower limbs absolutely "icy," the wounded limb being colder even than the other. Before ascribing this coldness to arrested circulation, the patient should be slowly and gradually warmed by local and general measures. Abolition of the peripheral pulse is also not a pathognomonic sign, because in a patient whose arterial tension is low a venous hæmatoma may compress the main artery sufficiently to obliterate an already feeble pulse. Purely nervous lesions, too, may retard, or even abolish, the pulse.

Pulsations synchronous with the pulse immediately suggest arterial hæmatoma. It must not be forgotten, however, that a venous hæmatoma may transmit the pulsations of a neighbouring artery, sometimes with great distinctness. On the other hand, the absence of pulsation and of expansile movements does not necessarily exclude arterial hæmatoma. In the voluminous and rapidly forming hæmatomata, such as

I have described, the expansile movements of the tumour at once strike the eye. In medium and small hæmatomata, on the other hand, they are extremely difficult to detect.

A systolic murmur, however, is pathognomonic, and the use of the stethoscope in doubtful cases cannot be too strongly insisted upon. At the same time, it will not determine the diagnosis in every case. If a murmur can be detected, arterial injury is certain, but from the absence of a murmur no positive conclusion can be drawn.

Inflammatory distension, corresponding to a commencing local infection, may also cause localised or diffuse distension of the limb in the early days after the wound. Localised or diffuse inflammatory swelling, due to commencing local infection, is sometimes observed in the days immediately following injury. A wound in the neighbourhood of a large trunk suggests a vascular lesion, although the symptoms all point to a circumscribed suppuration in process of development. The skin is hot, red, distended, and glossy, and there is a rise in the axillary temperature. Although these signs are those of a circumscribed suppuration, they may all be present in arterial hæmatoma. Also diffuse distension of a limb, the calf, for example, is equally suggestive of diffuse arterial hæmatoma or of deep-seated gaseous cellulitis. The differential symptoms are pulsation and a murmur, but they are not invariably present. In such cases the diagnosis must remain doubtful.

Thus, in spite of a searching examination, the surgeon may at first fail to recognise an arterial hæmatoma. The condition may be mistaken for a simple venous effusion of little clinical importance,

for a circumscribed suppuration, an abscess, or a deep-seated sepsis. Such an error in diagnosis may be attended by serious consequences. Are there no other diagnostic factors which may be relied on in doubtful cases? There are two symptoms which are practically never absent in these arterial lesions; they are loss of power in the limb, and pain.

When there is no serious vascular or nervous lesion, even quite large wounds of the soft parts are accompanied by nothing more serious than some discomfort and a comparatively slight loss of power. Hence if the wound is a small one unaccompanied by fracture, the patient is usually able to move the limb without much difficulty. But when a large vascular trunk is injured, the case is very different. Let us suppose a wound of the popliteal space. The leg is immovable; it is flexed on the thigh, which is in a position of abduction and external rotation. By pressing his hand on the outer side of the injured knee the patient endeavours to prevent any movement of the limb. The attempt to extend the leg in order to examine the wound provokes a reflex contraction and very severe pain. I have often been impressed by this powerlessness, which does not seem in accordance with an apparently harmless wound without fracture. In such a case a vascular or nervous lesion should be suspected. The presence of swelling or hæmatoma settles all doubt; there is a lesion of the main artery.

A patient with a wound of the calf or thigh is sometimes brought to the dressing station complaining of intense, deep-seated, and persistent pain, in spite of the fact that his wound presents only a diffuse swelling, ill-defined in character and difficult of

detection. This pain is a cardinal symptom. Deep-seated pain which is not increased by pressure can only be due to deep-seated distension of the tissues, and during the first hours after injury such distension can only be caused by deep-seated effusion of blood, that is to say, by a diffuse hæmatoma.

Lastly, vascular injuries frequently lead to the speedy appearance of serious general symptoms. A wound of a main artery may not only at once react on the heart, producing tachycardia with dilatation, but it frequently affects the general condition of the patient to a very marked extent. I have described above the combination of symptoms characteristic of traumatic shock. Nowhere is its onset more rapid than in the case of wounds of the large vessels. Is this due to the fact that these vessels are surrounded by a peculiarly sensitive sympathetic plexus? I do not know. But in the case of apparently quite simple wounds, I have often been able to conjecture, if not actually to diagnose with certainty, from the nature of the general symptoms, the existence of a deep-seated vascular injury.

In doubtful cases, then, in the absence of local pathognomonic symptoms, an arterial hæmatoma may be distinguished from a venous hæmatoma, from a circumscribed suppuration, or from the beginning of deep-seated sepsis, by a combination of local and general symptoms sufficiently definite to point the way to a correct diagnosis.

Having diagnosed a case as one of arterial hæmatoma, what will be its clinical course?

Clinical Course of Diffuse Hæmatoma

1. **A LARGE AND RAPIDLY-FORMING HÆMATOMA** is inevitably associated with serious complications.

A. *Ischæmic gangrene.*—In a large group of cases. gangrene of the wounded limb, or of the portion of the limb below the wound, takes place either at once or very rapidly. This is due not only to division of the main artery of the limb, but more particularly to increasing compression exerted by the effused blood upon the collateral circulation. I have already shown that it is only exceptionally that ligature of a main artery causes gangrene of the parts supplied by it; this only takes place when the collateral circulation is arrested. An extensive hæmatoma constitutes an almost insurmountable obstacle to the development of the collateral blood-supply.

In spite of everything that can be done, the limb remains cold, pale, and insensitive; the skin is icy-cold to the touch; the extremities become livid; the fingers and the hand or the dorsum of the foot, as the case may be, are covered by more or less confluent red blotches; and the skin dries up, shrivels, and turns black. This is the dry form of gangrene, and it is very rare. Fig. 85 shows a case of dry gangrene of the fingers and part of the left hand of a patient with hæmatoma of the axilla. But more commonly the epidermis is detached, and blisters filled with a reddish serous fluid are formed. Later the skin turns black or greenish in colour, and becomes deliquescent. This is the moist form of gangrene, and in actual practice it is almost the only form encountered. We shall see the reason for this directly.

The first appearance of gangrene is accompanied

by very strongly marked general symptoms. These symptoms are associated with an intense toxæmia originating at the seat of the disease, the onset of which is dramatic in its suddenness. In the course of a few hours the system is invaded by toxins in enormous quantity, and the patient succumbs rapidly, even amputation of the limb being unavailing.

B. *Ischæmic and septic gangrene.*—This class of case is characterised by the sudden development of very serious infection. I need not repeat that shell-

Fig. 35.—Dry gangrene of the hand following a wound of the axillary artery. (Lefort.)

splinter-wounds, owing to the septic condition of the torn and lacerated tissues, specially predispose to the occurrence of serious sepsis. Bullet-wounds, however, must not be regarded as immune. Here the track is distended by the effusion of blood, which forces it apart and, as in the case of shell-wounds, forms a kind of deep-seated incubation chamber, where the colonies of microbes carried in by the bullet may multiply at their ease.

The bruised and ragged track of a shell-wound, excluded as it is from light and air, is a singularly favourable *milieu* for the development of the germs

conveyed by the missile and the débris which it carries with it. They develop with incredible rapidity, and in a few hours induce very serious local sepsis, generally with the formation of gas in the wound. Thus arises the most serious form of gas gangrene, which originates and develops beneath the aponeuroses and muscles in the deep-lying tissues apparently out of reach. The traumatised area is predisposed to gangrene by reason of the extreme local anæmia, the immediate appearance of trophic lesions due to arrest of the blood-supply, and the continued pressure of the effused blood on the devitalised tissues. Thus, when it is exposed to invasion by microbes whose virulence has become intensified by the favourable conditions of their *milieu*, it is not surprising that the most serious septic complications at once appear. Moreover, these gas-forming microbes evolve it in the devitalised area, whence the gas invades the neighbouring tissue spaces and insinuates itself for some distance between the muscles, which it compresses. The collateral circulation is thus finally blocked by the added external pressure. A few hours later gangrene appears, a gangrene at once ischæmic and septic, which speedily poisons the patient and kills him. It is impossible to lay too much stress on the enormous importance of arterial lesions, especially of diffuse hæmatoma, in the etiology of gas gangrene, the most formidable complication to which wounds are subject.

2. A SMALL AND SLOWLY-FORMING HÆMATOMA.—The development of medium-sized or small hæmatomata varies considerably according to the case. It may be generally accepted that, with a few exceptions, the progress of the wound is determined by the nature

of the missile. In the case of a shell-splinter, the wound should be regarded as infected from the first. In the case of a bullet, it may be regarded as primarily aseptic; infection determines the progress of the hæmatoma.

A. In association with Shell-wounds.—Every shell-wound is contused and infected, the degree of infection ranging from the most diffuse gaseous sepsis to the smallest circumscribed suppuration.

(*a*) *Gas gangrene.*—In some cases the original infection takes the form of gas gangrene from the beginning. It has been shown that the traumatised area presents remarkably favourable conditions for its development. Hæmatomata of moderate size are singularly predisposed to it. Among other cases I remember an infantry captain, exceptionally tall and strong, who was brought to me in May 1915 with a perforating shell-wound of the thigh. The thigh was much swollen and distended, but the tumefaction was most marked on the posterior and external parts. Suspecting a deep-seated hæmatoma consequent on a wound of the deep femoral, I opened the hæmatoma and evacuated it. It was due to a wound of the second or third perforating artery, and this I ligatured. Although I left the wound open, freed the surrounding muscles, and incised the tissues on all sides, I could not overcome the septicæmia which had originated in the area of the hæmatoma, and four days later the patient died. It cannot be too often repeated that hæmatomata, even the smaller ones, have a dangerous predisposition to gaseous cellulitis.

(*b*) *Diffuse cellulitis and circumscribed abscess.*—The earlier stages of the primary infection are not always of this extreme virulence. Some hours after

the injury, usually not later than the next day, the skin in the region of the wound and all over the swollen limb becomes red and œdematous. From the wound itself a sero-sanguineous fluid, which may be either purulent or sanious, exudes. The skin around the wound is hot, distended, and tender on pressure. Pain, which has been constant since the injury, increases, and becomes more intense; it is aggravated by the least movement or the slightest pressure. At the same time the temperature rises, reaching 101° or 102° Fahr.; the pulse is rapid, the tongue dry, and the urinary-secretion diminished. In short, all the symptoms of commencing suppuration are seen.

In certain cases this suppuration may lead to local complications, which rapidly become dangerous. The tumefaction spreads, extending above the wound as far as the root of the limb. The condition is that of true diffuse cellulitis, imperilling life and limb. In other cases, whether because the wound being larger it allows the septic fluid to escape freely from the first, or whether because it has been surgically enlarged, the complications are less serious. The sepsis is localised, and the condition corresponds to circumscribed suppuration.

The most serious and most frequent complication, however, is secondary hæmorrhage.

Secondary hæmorrhage.—This is justly regarded as the most dangerous complication of wounds. It may proceed from newly-formed capillary vessels, arterioles, or large arteries. Hæmorrhage from newly-formed capillary vessels occurs in septicæmic and debilitated patients during the course of septic wounds, in compound fractures, and in open stumps after amputation. The wound is pale and atonic, the granulations are

sparse and pale, and fill the drainage tubes with little fungating plugs. A day comes when, without any apparent cause, a sanguinous oozing takes place in the wound, which without being copious is yet sufficient to place the enfeebled patient in immediate danger. Hæmorrhage of this type is late, scanty, and recurrent.

Hæmorrhage from the arterioles occurs in the course of contused and septic wounds of the forearm, hand, buttocks, calf or foot, which, having been very freely opened up, have escaped early complications. As the wound clears up, however, its walls gradually necrose and come away as sloughing shreds. Small vessels included in the contused and gangrenous area also undergo mortification, and about the sixth, eighth, or tenth day the walls of these may suddenly give way. Sometimes the bleeding occurs during the dressing of the wound, but sometimes it takes place in the night, without apparent cause. The patient, feeling the moisture, calls out; by that time the dressing is completely soaked, and the bed is stained with blood. The dressing is rapidly removed, the wound packed, and the result watched, though generally not for long. Next day, or very soon after, a fresh hæmorrhage takes place. The wound is again packed, and the hæmorrhage arrested a second time. But the patient, who was left by the first hæmorrhage in a very enfeebled condition, is now very seriously affected, and if a third attack cannot be warded off by means of antipyrin, adrenalin, or gelatine serum, he will certainly die. Hæmorrhages from arterioles or from small arteries, such as the radial, the gluteal, the peroneal, etc., are early, copious, and repeated.

During the early days secondary hæmorrhage from

a large artery follows very rapidly on the opening, whether spontaneous or surgical, of a circumscribed cellulitis. This class of hæmorrhage is the most grave. In the case of a penetrating wound of the axilla or upper part of the limb with some swelling, the patient may have been under observation in hospital, he may even have been discharged without his arterial hæmatoma having been discovered. Symptoms of purulent inflammation then appear, and, either spontaneously or after incision, putrid clots escape from the wound, followed by bright red blood in a quantity which from the first may be alarming. In the vast majority of cases the accident occurs in the absence of the surgeon; the patient, who up to then has been feverish, and from whose ill-drained wound a copious sanious fluid has exuded, suddenly finds his dressing saturated. Terrified by the sight of blood, he calls out and faints. He is found bathed in blood and pallid, with colourless mucosa and dilated pupils. Death often supervenes in a few minutes without any chance of surgical intervention. In other cases the occurrence takes place under the eyes of the surgeon, who opens what he supposes to be a cellulitis and finds putrid clots. The cleansing of the wound is followed by dangerous hæmorrhage. As a general rule, this circumstance is favourable, for it enables the operator to secure permanent hæmostasis on the spot. Nevertheless death is sometimes almost instantaneous, as in a case where a tonsillar swelling, which had been regarded as an abscess but proved to be a septic hæmatoma of the carotid, was opened by way of the mouth. Secondary hæmorrhages from main arteries, such as the carotid, subclavian, or common femoral, are early, single, and very copious.

Thus arterial hæmatoma consequent upon shell-wounds of the vessels may lead either to primary complications of extreme gravity, such as gas gangrene or diffuse suppuration, or it may give rise to secondary complications which are equally serious, namely, cellulitis either circumscribed or diffuse, sepsis either rapid or tardy, but always involving the risk of serious secondary hæmorrhage.

B. In association with Bullet-wounds.—As a general rule, the chief characteristics of bullet-wounds are their comparative insignificance and their freedom from sepsis.

I have already shown that in the absence of sepsis, by reason of its comparatively small size, the arterial hæmatoma undergoes anatomical changes which lead gradually to the formation of an arterial or arterio-venous aneurism. I have described the manner in which a sac wall, circumscribed and amenable to extirpation, is gradually formed around a cavity of varying size, which is in direct communication with the lumen of the artery. The clinical picture is that of a traumatic arterial aneurism, which differs considerably from arterial hæmatoma. When a hæmatoma is opened it empties itself at once; the tightly packed clots escape, and the surrounding tissues, in which the distension had created a cavity, return at once to their normal position, thus obliterating the space occupied by the clots. The results of opening an old traumatic aneurism are very different; fluid blood escapes freely, the incision gapes, but the wall of the sac does not collapse. We have here two widely divergent anatomical conditions, the second of which is, however, the outcome of the first. Is it possible to determine the length of time required

for an encysted hæmatoma to become an arterial aneurism? This varies naturally with the vessel, its calibre, and the size of the primary hæmatoma. Experience, however, shows that the encysted hæmatoma does not acquire a distinct aneurismal sac until five or six weeks after the injury. As a general rule, the anatomical stage may be determined by well-marked clinical signs.

The tumefaction, at first diffuse, becomes gradually more circumscribed, while at the same time the œdema and distension diminish, and the rest of the limb assumes an appearance more nearly approaching the normal. The early symptoms of pain and powerlessness gradually decrease, the condition becomes stationary for a time, and the stage of traumatic aneurism is reached.

Arterial aneurism.—Traumatic arterial aneurism presents the following features: along the course of an artery, and at a point corresponding to an old bullet-wound, a tumour appears, usually regular in form, smooth and ovoid in shape, and varying in size from a pigeon's egg to a closed fist (fig. 36). The surface is smooth and regular, and the consistence varies with the age of the tumour. The more recent the tumour, the softer, more compressible, and fluctuating it is, becoming harder and more resistant as it gets older. It is generally fixed, and cannot be moved either transversely or in the long axis of the limb.

On inspection of the tumour, pulsation and regular movements of expansion are distinctly perceived. These coincide with the pulse. On auscultation a murmur, more or less harsh in character and synchronous with the cardiac systole, can be made out. It is due not to vibration of the orifice between the

artery and the aneurism, the edges of which are curled up and well coated with endothelium, but to the vibration of the successive waves of blood which meet and form an eddy in the interior of the sac. The murmur is loudest at the centre of the tumour, and becomes less distinct as the stethoscope is moved towards the periphery.

Investigation of the pulse below the aneurism gives important information. It is less strong than that of

FIG. 36.—Arterial aneurism of the left ulnar artery, following a gunshot-wound. (Tanton.)

the opposite side, and is also delayed in time, this retardation being pathognomonic of arterial aneurism.

Compression of the peripheral end of the artery increases the intensity of the pulsations, the expansion and the murmur, while compression of the central end diminishes the tumour and abolishes the pulsations and the murmur.

Besides these physical signs there are subjective symptoms, the intensity of which vary with the case. Occasionally there is practically no pain or discomfort, but it is more usual to find subjective symptoms

corresponding to lesions of the neighbouring structures. It has been shown that peri-arterial hæmatoma is accompanied by pain due to tension of the deep tissues, and by loss of function consequent upon muscular contraction due to the effusion of blood. The retraction and limitation of the hæmatoma usually modify these troubles, but seldom abolish them altogether. On the contrary, owing to the contraction of the peripheral connective tissue at the circumference of the sac, all the peri-arterial structures included in this sclerosed tissue are drawn down into it and become incorporated with it. This results in œdema of the limb from venous compression, neuralgia, paralysis and atrophy from compression of the nerves, and ischæmic paralysis due to sclerosis of the muscles. These functional disturbances, the intensity of which varies according to the case, have a large share in determining the details of surgical treatment.

Arterio-venous aneurism.—An arterio-venous aneurism does not, as a rule, attain the dimensions of an arterial aneurism.

I have already described the derivative action which, in simultaneous arterial and venous injury, is exercised upon the arterial hæmatoma by the central end of the vein. I have also pointed out that the circumscription of the arterio-venous hæmatoma is very rapid, and that it tends to become transformed into a sacculated arterio-venous aneurism.

When it has reached a sufficient size, the arterio-venous aneurism shows itself as a limited and more or less reducible swelling of soft consistence. It pulsates synchronously with the pulse, and also shows movements of expansion. Its dominant feature is

the thrill, which is best described as a kind of vibration similar to that caused by the vibration of a metal disc. Once experienced, it can never be forgotten.

On auscultation a continuous murmur is heard, which grows louder at each systole. The systolic beat is sometimes soft and musical, at others louder, resembling the clapping of the valves in aortic disease. These sounds are most distinct at the point corresponding to the site of arterio-venous communication. Slight compression at this point causes the thrill, pulsation, and bruit to disappear. The thrill is transmitted above and below the aneurism. In a case involving the hypogastric (internal iliac) vessels, upon which I operated with Cotte, a very strong thrill extended from the internal malleolus to the apex of the heart. The systolic murmur is also transmitted towards the periphery. The continuous murmur diminishes in intensity with the distance from the aneurism, until the systolic sound alone is audible.

Above and below the tumour the injured vessels present the following characteristics: towards the heart the pulse is full and strong, more so than on the sound side; towards the periphery it is weaker, and is sometimes imperceptible. As in the case of arterial aneurism, compression above increases the symptoms, compression below diminishes them.

In addition to these physical signs there are also functional symptoms of varying intensity, corresponding to diminution of pressure in the peripheral arteries, and to increase of pressure in the peripheral and central veins. On the peripheral side there is functional derangement by œdema and cyanosis of the limb, tingling, cramp, neuralgic pains, and sometimes

a sensation of cold in the extremities; and on the central side by palpitation, breathlessness, and dilatation of the right side of the heart.

It is in this manner that, in a large proportion of cases, arterial hæmatoma following a bullet-wound leads to the formation of an arterial or an arterio-venous aneurism.

Complications.—In a small number of cases the course is disturbed by complications, which may be grouped under two heads :—

1. Sudden and rapid enlargement of the hæmatoma.
2. Infection of the hæmatoma.

1. *Sudden and rapid enlargement of the hæmatoma.*—This enlargement generally takes place in the first days after injury. The clot which had temporarily obstructed the arterial wound becomes softened or displaced. The patient having somewhat recovered from the shock of the initial injury, the systolic beat is stronger, and, under its influence, an infiltration of blood takes place which may acquire enormous proportions. In certain cases of arterio-venous hæmatoma the sudden enlargement is due to the obstruction by a clot of the venous orifice, which until then had sucked in the arterial blood, thus preventing increased hæmorrhage. Morestin reports an interesting case of this kind. It was a case of arterio-venous hæmatoma of the axillary vessels, with thrill and continuous murmur, but with no great swelling, and without much functional disturbance. One day the swelling suddenly increased, the ecchymosis spread, and very severe pain was complained of, whilst the thrill and the continuous murmur disappeared. A clot had closed the vein and blocked up the derivative channel.

Whatever may be the cause, sudden enlargement

of the hæmatoma leads to complications of extreme gravity, to gangrene of the limb, or sloughing of the skin over the surface of the tumour.

Gangrene from ischæmia of the limb is due to centrifugal pressure, to the obliteration of the collateral arterial channels by the effused blood; and sloughing of the skin by centrifugal pressure occurs when the effusion, restrained by resistant anatomical planes from passing into the deeper tissues, extends towards the surface of the body. The skin gets pale and becomes gradually thinner, and a sloughing patch appears on the top of the tumour. The speedy separation of the slough causes not only the discharge of the contents of the hæmatoma, but its certain infection.

In cases where the enlargement of the hæmatoma does not lead to gangrene or rupture, it may result in serious complications due to compression.

Compression of the veins is followed by rapid and considerable œdema of the limb, which may be mistaken for suppuration. Persistence of the œdema is accompanied by loss of power, and finally by complete functional muscular and nervous disorganisation which renders the limb useless. Compression of the nerves produces paralysis, anæsthesia, trophic and vasomotor disturbances, and pain which is sometimes intolerable. Paralysis of the median, ulnar, or external popliteal nerve may be produced or be increased in this manner, or paralysis of all the nerves at the root of a limb may occur. Finally, compression of the muscles is accompanied by a varying degree of ischæmia, which may sooner or later result in muscular degeneration and ischæmic paralysis.

2. *Infection of the hæmatoma* is not as uncommon as the insignificant characteristics of the external wound

would suggest. The effusion of blood turns the potential track of the bullet into an actual track. It fills this track with clots, which are highly susceptible to infection. These clots insinuate themselves by degrees across the aponeuroses and the muscles, finally reaching the near neighbourhood of the cutaneous wound by an irregular and tortuous track. Thus although there may be no primary infection from the passage of the bullet, a secondary infection proceeding from the small cutaneous wound may in this way reach the deep parts. This may give rise to a deep infection, either circumscribed or rapidly diffuse, and in either case a suppuration may occur, leading to secondary hæmorrhage.

A comprehensive review of the anatomical and clinical development of arterial hæmatomata shows that large and rapidly formed hæmatomata very soon lead either to ischæmic gangrene or to ischæmic and septic gangrene of the wounded limb; that medium-sized, slow-forming hæmatomata if primarily infected, as in shell-splinter-wounds, lead to rapid sepsis and secondary hæmorrhage. When, however, such hæmatomata are aseptic, as is usually the case with punctiform bullet-wounds, they lead to the regular and slow formation of arterial or arterio-venous aneurisms. This favourable development may, however, be disturbed by complications, such as rapid enlargement, rupture, or infection, which introduce the grave symptoms incidental to large septic hæmatomata.

3. Wounds of Vessels without Hæmorrhage

Not the least of the clinical surprises of this great war has been the discovery of the dry arterial wound

(Fiolle). It has been observed by all surgeons in the neighbourhood of the firing line, and the rationale of its method of production is now known.

A dry arterial wound may occur in association with bullet-wounds. The artery is completely severed; spontaneous hæmostasis is effected by the curling up of the tunica intima; there is no bleeding.

Or the bullet may injure an artery and a vein simultaneously and, passing between them, cause two lateral wounds facing each other and uniting by suction at their cut edges. A few drops of blood in the sheath constitute the only hæmorrhage, the arterial blood being rapidly drawn into the path of least resistance by reason of the venous aspiration. No hæmatoma is formed.

Sometimes the same is observed in connection with shell-wounds. A deep-lying artery is struck by a projectile, which tears it but remains fixed in the arterial wound. Fig. 10 represents a wound of the posterior tibial by a splinter which has stuck in the arterial wall, the wound being absolutely bloodless. Sometimes it is a scrap of clothing, a fragment of accoutrement, or a shred of leather which stops the vascular orifice and temporarily prevents hæmorrhage.

Lastly, in many cases the contusion of the vessel, extending well beyond the wound, induces rapid arterial thrombosis. The floating shreds of the internal and middle coats block the vessel for half an inch or more above the wound, and furthers the rapid formation of a clot. Here again we have a dry arterial wound. This form, like the others, was discovered fortuitously in the course of an incision to relieve tension.

Clinically, these arterial wounds without hæmato-

mata are often unrecognised. There is nothing to suggest an arterial wound: no hæmorrhage, external or internal; no hæmatoma. The sole factor liable to excite remark is, that the cutaneous injury is situated in the course of a large vessel. But even with this guide the most searching clinical examination fails to reveal the vascular lesion. Dry arterial wounds are accordingly rarely recognised in the first instance, but are revealed only by the complications to which they give rise.

When a shell-wound is properly treated by free incision exposing the site of injury and excising the track of the missile, the vascular injury cannot be overlooked. The situation of the cutaneous wound and the direction of the track in the neighbourhood of important vessels necessitates a minute and careful operation. Before making the first incision, an assistant should be ready to compress the main artery at the root of the limb, after which the edges of the wound and the walls of the track are carefully dissected out by cautious incisions. In such circumstances an arterial wound cannot escape notice.

If the incisions have been superficial and the depths of the wound have not been explored, the arterial injury will be overlooked, with the result that the contused and infected wound becomes purulent, and a circumscribed suppuration, if no more serious complication, results. External secondary hæmorrhage or diffuse secondary hæmorrhage speedily follows, according to whether or no the damaged area has free communication with the exterior. It is generally at the base hospitals that this grave complication is observed. The patient is brought in with a suppurating wound which has not been thoroughly opened

up; when this is done, the interior is found to be completely lined with granulations. Sometimes it is merely drained. The suppuration appears to be diminishing, when a secondary hæmorrhage, either single or repeated, supervenes, and may lead to death.

In the case of a bullet-wound the vascular injury is almost sure to be overlooked. At first no reason for operation is apparent; the patient is discharged, and the vascular wound is not diagnosed until later, often by a mere chance. As I have shown, it is sometimes discovered during an operation. But it is more often recognised clinically, generally by chance, although it is sometimes suggested by the appearance of slight functional symptoms corresponding to a small arterial aneurism or an aneurismal varix.

Aneurismal varix is the simplest form of arterio-venous aneurism. It is characterised by the anastomosis of an artery and a vein, with more or less dilatation of the central end of the vein. Clinically speaking, it is generally discovered by chance, as when on passing the hand over the neck of a patient an unexpected thrill is felt. This thrill, together with the continuous murmur augmented at each systole, which is so frequent in arterio-venous aneurism, is the essential and characteristic symptom of an aneurismal varix. Except for the tumour, this condition is an arterio-venous aneurism, and I need not repeat what I have already said upon the subject.

To sum up. In shell-wounds, dry wounds of the arteries lead sooner or later to secondary hæmorrhage. In bullet-wounds, they may terminate in spontaneous recovery, though more frequently they lead to the formation of a small arterial aneurism or an aneurismal

INDICATIONS FOR AND METHODS OF TREATMENT

I. Internal Hæmorrhage

The object of treatment is to arrest persistent internal hæmorrhage, to prevent the recurrence of hæmorrhage which has been temporarily arrested, and to combat the anæmia.

I do not propose to enter here into the details of such treatment. The management of thoracic and abdominal hæmorrhage is one of the most interesting details of the treatment of thoracic and abdominal wounds, but this is not the place to enlarge upon it. It is sufficient to say that intra-peritoneal hæmorrhage constitutes one of the most imperative indications for immediate laparotomy. Pleural hæmorrhage, on the contrary, seldom calls for exploratory thoracic operation unless the precise vessel which has been wounded has been ascertained. When the pleural hæmorrhage is of parietal origin, it is clearly amenable to direct surgical hæmostasis. When, however, it is derived from the root of the lung, although in theory it should benefit from surgical intervention, in practice it is almost invariably beyond the resources of surgery.

II. Arterial Hæmatoma

1. Extensive and Rapidly-forming Hæmatoma

In this class of case the therapeutic aims are largely preventive. Ischæmic gangrene is a very probable complication; a gangrene which is both ischæmic and septic is an almost certain one.

To prevent ischæmic gangrene it is necessary to evacuate the hæmatoma, the centrifugal pressure of which obliterates the collateral circulation, and to guard against its recurrence by permanent hæmostasis of the arterial wound. To prevent a gangrene which is both ischæmic and septic the wound should be freely opened, and all its ramifications laid bare. Both objects are obtainable by a single operation. The following are the different steps: All clots, which are very susceptible to infection, all infective portions of clothing, as well as the missile itself, should be removed; the blind contused wound should, in short, be transformed into an open and clean one.

1. *Preventive hæmostasis.*—Experience shows that the opening of a large hæmatoma should never be undertaken without first securing as complete a provisional hæmostasis as possible. It has been said that preventive hæmostasis may be dispensed with; as a matter of fact it is possible to open a large hæmatoma, rapidly to evacuate the clots which it contains, and, after having discovered the wound, to seize the artery and tie it. The manœuvre is one, however, which should never be attempted. The hæmorrhage may from the very outset be overwhelming. It is impossible to distinguish anything, and the sole resource is to apply a forceps at random. This may easily tear the vessel and increase the hæmorrhage. Or, with the wounded vessel an important nerve may be seized, the ligaturing of which may involve the worst complications. The results of opening a large carotid, subclavian, or axillary hæmatoma without preventive hæmostasis are beyond description. I well remember a case of a large

arterial hæmatoma at the base of the neck which was operated upon by one of my chiefs without this precaution. The sac was hardly opened when a fearful hæmorrhage bathed us from head to foot. Putting my hand into the wound I gripped the carotid with the forceps, but was unable to arrest the hæmorrhage, and the patient died on the table in less than two minutes. The vertebral had been divided behind the common carotid. I am firmly convinced that preventive hæmostasis is an indispensable condition of operation.

The simplest means of securing hæmostasis is to apply an elastic band, such as an Esmarch's tubing, round the limb above the wound. This procedure is not applicable to hæmatoma in the neck or at the root of limbs, and in any case I believe it to be dangerous. Short as is the time of its application, Esmarch's tubing induces a vasomotor paralysis of the arterioles and small veins on which the collateral circulation depends, and this must constitute a serious obstacle to the re-establishment of the circulation. Momburg's method has even less to recommend it. It is a barbarous proceeding, which consists in applying a very tight elastic band round the body between the floating ribs and the pelvis in order to suspend the circulation in the lower half of the body.

Digital compression of the vessel above the tumour is much simpler, much less dangerous, and equally efficacious. Unfortunately it can be applied only to hæmatomata situated in the limbs, and is not applicable to those at the base of the neck or at the root of the limbs.

In this latter case the vessel is laid bare by a suitable incision, and direct temporary hæmostasis

is effected. In the case of a carotid hæmatoma the artery is exposed at the base of the neck; in the case of the axillary, the third portion of the subclavian; and if the hæmatoma is at the root of the thigh, the external iliac. It is unadvisable to tie the exposed vessel with catgut, as the risk of dividing the internal or even the middle coat is considerable. In such a case, removal of the ligature after operation leaves an arterial thrombus, which is extremely prejudicial to the re-establishment of the circulation. As a rule it is sufficient to raise the artery and kink it over a piece of coarse catgut, thus obliterating the lumen. This method has another advantage besides its harmlessness. If, after opening the hæmatoma, there is any difficulty in detecting the arterial wound, it is easily found by relaxing the traction upon the vessel for a moment. I have operated successfully in this way on the common carotid, the subclavian, and the external iliac.

2. *Exposure of the wound in the vessel.*—After preventive hæmostasis has been secured, the hæmatoma is laid open. Before doing this it is most essential to expose the hæmatoma very extensively. Where the vessel is in the continuity of a limb a free incision from one end of the swelling to the other should be made; where, however, the vessel is situated at the root of a limb or in the neck, a longitudinal incision is not sufficient; a musculo-cutaneous or an osteo-musculo-cutaneous flap should be raised. It may even be, as I shall show later in the case of the axilla, that exposure can only be effected by division of the pectoral muscles, or that the inner two-thirds of the clavicle must be temporarily resected before easy access to the subclavian or first part of

the axillary vessels can be obtained. I repeat emphatically that a very wide means of access is essential to the success of the operation.

When the hæmatoma has been exposed, it should be well opened by one free incision. The edges of the wound are held well apart by an assistant by means of two strong retractors, while the clots are rapidly cleared out and one or two swabs thrust into the wound. Risk of serious hæmorrhage is obviated by the preliminary hæmostatic measures, and the bleeding is frequently insufficient to soak through the swabs, which are removed one after the other and the vascular wound examined at leisure. This state of things is not invariable, however. In spite of the preliminary precautions, the blood may continue to well up from the depths of the wound, soaking the swabs and flooding the wound. This hæmorrhage may proceed from a wound of the accompanying vein, or from a collateral branch opening from the artery itself below the ligature; or it may proceed from another artery, or from a deep-seated collateral branch. I have seen many examples of such multiple arterial wounds.

It is essential that the source of the persistent hæmorrhage should be ascertained. The upper end of the vessel is compressed at the upper angle of the wound by means of a gauze pad held in the hand, and the pad is moved slowly down the entire length of the wound, so as gradually to expose the artery and its branches and lay bare the whole field of the hæmatoma. If there is bleeding from the wound in the main artery, the hæmorrhage is derived from a branch in the neighbourhood of the wound. If the continuity of the artery is unbroken, the latter

may be raised, when the branch will be seen as a taut cord, which may be seized with forceps. If the hæmorrhage is from the lower end, nothing is easier than to apply the forceps to the artery. If the wound in the artery remains dry, the blood may come from a neighbouring vein, and its origin will be revealed by its colour and manner of flow. The hæmorrhage may come from a deeper artery or one of its branches, which it is not always easy to find. I have already mentioned those bi-sacculate hæmatomata caused by simultaneous injury of the superficial and deep femoral arteries, examples of which have been reported by P. Duval and Mauclaire. It is sometimes very difficult to find the deep vessel by way of the narrow track which separates the two sacs. In such a case the track should be enlarged, both sacs emptied, and the vessel again sought for. The operation is always a delicate one, and it is frequently extremely difficult.

3. *Permanent hæmostasis.*—When the wound in the vessel has been fully exposed, it may be secured by ligature, forci-pressure, or suture.

Forci-pressure is an exceptional method, which should never be employed except in a case of absolute necessity, when it is quite impossible to do anything else. It will seldom be required when operation is performed early. It may be necessary in the case of a deep-seated artery such as the gluteal, where the injury is close to its exit from the pelvis, and ligature is practically impossible. Its application for forty-eight hours will secure permanent hæmostasis.

Ligature is employed after both ends of the vessel have been secured by forceps in a case of complete division; when the vessel is only partially divided it

is compressed by forceps above and below the wound. the vessel between is severed, and its ends are tied.

Ligature in a wound is a simple. easy. and effectual operation. Can it be said to be free from danger ?

When considering extensive wounds, I stated that the ligature of a main artery does not in itself endanger the vitality of the limb to any great extent. The same cannot be said, however, of ligature in hæmatoma.

According to statistics taken before the war, gangrene after incision of a hæmatoma and double ligature in the wound was not common. Among 157 cases collected in 1911, Monod and Vanverts found only ten cases of gangrene, or 6·3 per cent. Individual consultation with each surgeon who has had occasion to treat such cases at the front during this war gives a different impression of the serious nature of these lesions. I refer, of course, to extensive hæmatomata of important arteries, such as the lower part of the axillary, the external iliac or common femoral, or the lower end of the popliteal. I myself saw two cases of gangrene of the hand and forearm after incision of an axillary hæmatoma out of the five cases on which I operated, two cases out of nine after incision of large hæmatomata at the top of the thigh, and two cases out of five after incision of popliteal hæmatomata.

The great gravity of the operation is not surprising when we consider the intensity and the extent of the contusion caused by shell-splinters, the multiplicity of the vascular branches, arterial and venous, which are injured, the variety of the accompanying nervous lesions, and, lastly, the frequently enormous size of the hæmatoma which finds in the wounded

area a ready-made field for its rapid extension. The collateral branches which have escaped being wounded have been so compressed by the tense effusion, that it is only too probable that the resulting vasomotor paralysis will prevent the re-establishment of the circulation even after evacuation of the hæmatoma. These large, rapidly-forming hæmatomata are hardly ever seen at the base hospitals, such patients being cured before their arrival, or never getting there at all.

We see, then, that double ligature of the wound after evacuation of a large diffuse hæmatoma is an operation which, in the case of certain large arteries, is followed, in nearly one-third of the cases, by partial or total necrobiosis of the distal part of the limb.

In these circumstances it is of great importance to know beforehand whether the re-establishment of the collateral circulation is probable or not. The surgeon who is about to open a hæmatoma of the axilla will require a more specific guide than mere statistics if he is to make a wise choice between double ligature, simple, easy, and efficacious, and an attempt at vascular suture, which is complex, difficult, and perhaps less certain. Is it possible to foresee in each case the condition of the circulation of the limb after ligature? The attempt should at least be made.

If, after having provisionally checked the flow of blood in the artery for a few seconds, no signs of arrested circulation, such as coldness and lividity of the digits, are evident, we may hope that the circulation will be re-established. This rather vague indication may be confirmed by means of a small incision at the extremity of a toe or a finger, or even, as Quénu has suggested, by the exposure of a small

terminal arteriole, or an artery such as the dorsalis pedis. If the accompanying vein is compressed, and its distal end swells up rapidly in spite of occlusion of both ends of the wounded artery, the conclusion is obvious that the blood continues to flow into the limb and to return by the veins. Lastly, in cases when blood escapes from the lower end of the wounded vessel at the moment when the forceps are applied to it, as is well seen in the case of the external carotid, for example, there is no cause for anxiety, the collateral circulation is present, and is sufficient. If this triple test is negative, it is impossible to foresee the result of ligature.

Vascular suture (*arteriorraphy*) is an invaluable resource. When speaking of the treatment of extensive arterial wounds I compared the ligature. which is simple, certain, and without danger, with suture, which is equally certain, and equally free from danger, but more complex and of uncertain efficacy. In cases of that type, ligature was preferred on account of its harmlessness.

The greater risk of the ligature in large recent hæmatoma certainly increases the indications in favour of arterial suture. If suture is to be attended by complete success, by which I mean the maintenance of arterial permeability, the edges of the vascular wounds must, unfortunately, be freely revivified by paring them. This complicates the execution of the suture; it may convert a lateral wound, if not into a complete division, at least into one so extensive that lateral suture cannot be applied to it; and in the same way it may turn a complete division, with more or less ragged edges, into a loss of substance of an inch or more. Circular suture is, therefore,

most frequently indicated. In these circumstances it is not to be wondered at that the number of primary vascular sutures performed before the war was extremely small. Monod and Vanverts, in 1911, were able to describe only nine cases of diffuse arterial hæmatoma resulting from gunshot-wounds, and treated by incision and arterial suture. Of these nine cases, only three correspond to the large primary hæmatomata which are here under consideration. Since the war, Sébileau has reported a case of suture of the popliteal which did not avert amputation of the limb, and Couteaud described the suture of a lateral arterial wound which was unsuccessful. On the other hand, Pauchet and also Lemaitre have twice successfully sutured the femoral. Out of thirteen sutures performed by Soubbotitch, eight were lateral and five circular. The circular sutures were in all cases successful; of the lateral sutures, three failed and five were successful. For my own part, before the war I had on four occasions sutured the femoral artery in diffuse hæmatoma, resulting in two cases from knife-wounds, in one from a revolver-bullet, and in one from a petard-wound. I was, therefore, prepared for vascular suture in injuries of war, and have several times attempted it. But the extent of the vascular lesion and the intensity of the contusion of the walls have always obliged me to abandon it. Nevertheless I am convinced that the method should be persevered with. Great success has attended its employment in the treatment of aneurisms, and success should be equally possible, though perhaps less easy, in the case of diffuse hæmatomata. Before deciding on permanent ligature, it is advisable in cases where gangrene is feared first to attempt lateral

arterial suture where possible, and circular suture where necessary. Should suture prove impracticable, it is not too late to resort to ligature.

Venous suture is a perfectly useless proceeding. Suture of the femoral, axillary, or even the jugular vein, is never indicated, ligature in these cases being entirely free from risk.

4. *General treatment of the wound.*—When hæmorrhage has been finally arrested, the next endeavour is to convert the contused and lacerated wound into a clean one, which shall be dry and ready to heal. The method has been described above, and I need not repeat it here.

2. Medium-sized or Small Hæmatoma of slow growth

A. FOLLOWING A SHELL-WOUND.—The danger of immediate serious infective conditions, such as gangrene and diffuse cellulitis, as well as of infective conditions, the appearance of which, though less prompt, leads almost inevitably to secondary hæmorrhage, is an indication for immediate surgical intervention. The treatment of the vascular wound is here again only a special item in the treatment of this class of wounds in general. Every shell-wound should be promptly operated upon, especially when it is complicated by a wound of a vessel. It may happen that on the admission of the patient to hospital an arterial hæmatoma is not recognised. This may be due either to its small size and tardy development, or to a hasty and incomplete examination. Consequently the wound is insufficiently cleansed and dressed, and the patient discharged without further

attention. The vascular wound does not show itself until some days later, when sudden increase of the swelling or, more frequently, a secondary hæmorrhage takes place. The question of treatment resolves itself into the management of either of two very different conditions:—

1. A hæmatoma of medium size, recently formed and easily diagnosed.

2. A suppurating wound with either diffuse secondary hæmatoma or secondary hæmorrhage.

In the first case, the method is that which has just been described. The size of the swelling has no clinical significance. The same precautions and the same technique must be employed in the management of a small or medium hæmatoma as in that of a large one. These measures are provisional hæmostasis, free exposure and incision of the hæmatoma, and treatment of the vascular wound according to the instructions given above. I would remark that the smaller the hæmatoma and the less threatening the symptoms of compression, the less is the consequent menace to the collateral circulation and the less the risk of the double ligature.

In the second case, the work of the surgeon is often difficult. The most difficult problem is that of secondary hæmorrhage.

Treatment of Secondary Hæmorrhage.—It was not my original intention to enter here into the details of the treatment of secondary hæmorrhage. As a matter of fact, it does not occur if prophylactic treatment against infection is methodically and carefully carried out. Secondary hæmorrhage is no longer observed at front-line stations, where all wounds from large missiles are at once subjected to

the extensive surgical measures to which I have so frequently referred. Neither is it observed at base hospitals, where any imperfection or insufficiency of the surgical treatment at the front is immediately supplemented. Secondary hæmorrhage was much talked of at the beginning of the war, but no one mentions it to-day. Everybody knows that it is a sign of inefficient treatment; it is a living reproach to the operating surgeon.

Nevertheless secondary hæmorrhage does occur in rare instances, and such cases must receive appropriate treatment. They comprise those exceptional cases of hæmorrhage into the dressings in the atonic wounds of septicæmia, the more numerous cases in which hæmorrhage from an infected wound takes place as the result of an undetected wound in an artery of small or medium calibre, and the cases in which secondary hæmorrhage occurs as the result of the infection of an arterial hæmatoma which has either passed unnoticed or has not received early treatment. To these I would add secondary hæmorrhage as the result of secondary ulceration of large arteries, the ulceration being due to friction of the vessel against a foreign body, such as a missile or a bony splinter. Grégoire has recorded a case of this kind. It may also result from prolonged contact with a rigid indiarubber drainage tube. Finally, secondary hæmorrhage may take place after extensive denudation of a vessel, especially if the latter is in contact with extremely septic material, as in wounds of the neck or at the angle of the jaw, which communicate with the bucco-pharyngeal cavity

The capillary hæmorrhage of atonic and septic wounds is treated by complete removal of the granu-

lations, and the minute and careful curetting of the wound. This is the ideal mode of disinfection. Hæmorrhage of this sort cannot be arrested by sprinkling the granulations with local medicaments, or by exhausting the entire series of hæmostatic remedies. The whole area of the wound must be curetted, incisions being made where necessary, until the underlying healthy tissues, aponeurosis, muscle or bones, are plainly seen. When all the septic granulations are removed, the hæmorrhage will cease of itself. The post-operative measures include the employment of heliotherapy and hot air—not chemical antiseptics, but the physical agents, light and heat.

Secondary hæmorrhage of arterial origin is by far the most frequent. The sole method of treatment is by immediate operation. Owing to the nature of their origin there is great risk in attempting to arrest these hæmorrhages by timid and imperfect methods, such as compression in the wound, which is both ineffectual and dangerous. It is ineffectual, because the hæmorrhage recurs with each change of tampon, and frequently reappears in spite of plugging. It is dangerous, because the close plugging of a septic wound increases the infection, endangers the vitality of the walls, and leads, in the end, to a serious and rapid extension of the sepsis. The only rational method is by immediate operation.

The first operative measure is the free exposure of the traumatised area; the second, the isolation of the bleeding vessel, and its ligature above and below the opening.

In infected tissues such an operation presents considerable difficulty. In the first place, it is not

always possible to open up the traumatised area. As the result of œdema and infiltration, the walls are rigid and fail to collapse; the wound remains deep and rugged, especially if it be in the neighbourhood of a bony surface, as around the trochanter, in the popliteal space, or in the gluteal region. Thus operation is performed at the bottom of a rigid cavity into which it is difficult to see. That cavity is, moreover, carpeted with granulations, covering a layer of hard tissue, in the very midst of which the wounded artery is concealed. The spot from which the bleeding takes place is seen at the bottom of the wound, and an attempt is made to catch the artery with the forceps, but the points tear the tissues and do not hold. It is only after considerable trouble, and not always even then, that the forceps are at last fixed and the hæmorrhage arrested. The replacing of the forceps by a ligature is also very difficult. Either the extremity of the forceps cannot be disentangled, or the ligature breaks, and the manipulation has to be repeated. One or more forceps must sometimes, therefore, be left in place. In such a case as this forci-pressure fulfils one of its most valuable indications.

In the face of these difficulties, it has been suggested that ligature in the wound should be replaced by ligature at a distance. The finding and controlling of the actual source of hæmorrhage being a matter of difficulty, would it not be well to tie the artery above the wound in sound tissues where the anatomical landmarks would enable it to be easily found? Theoretically, ligature at a distance is very inferior to ligature in the wound. It may be useless, it may be ineffectual, and it may be dangerous; useless, if

it is applied, for example, to the axillary below the clavicle for a hæmorrhage in the axilla, the source of which is a wound of the subscapular, which continues to bleed; ineffectual, if between it and the opening in the vessel there is a collateral branch conveying blood into the wound; and dangerous, if it can only arrest the hæmorrhage by interfering with the collaterals on which the restoration of circulation in the limb depends. But in spite of these undoubted drawbacks, ligature at a distance remains the last resource in difficult cases.

Where and how should it be performed? Must a fresh incision be made away from the wound, the artery found, and a provisional ligature applied to it? Or may the wound be merely enlarged in an upward direction until the vessel is found in healthy tissues? This depends, I think, upon the nature of the case.

In cases where it is easy to enlarge the wound in an upward direction until the artery is found, this should be done directly and without a fresh incision. As soon as the artery is found it should be tied as near to the bleeding point as possible. This is generally the best method in wounds of the calf, the forearm, or the arm. But if the wound is difficult of access, if its walls are rigid, or if, above all, the vessel changes its direction above the wound, as happens in the case of the popliteal and the gluteal, it is better at once to apply a temporary ligature in healthy tissues away from the wound. Thus ligature of the external carotid is very successful in hæmorrhage from some wounds of the neck, the face, or the bucco-pharyngeal cavities; ligature of the femoral at the adductor opening in wounds of

the popliteal space; and ligature of the hypogastric (internal iliac) in some deep wounds of the buttock. But ligature is only the first step in the operation. The second is equally indispensable. It consists in thorough opening up of the wound, which is now protected from all risk of hæmorrhage, curetting of its walls, and as complete an exposure of the vascular wound as the conditions permit, followed by isolation of the vessel and double ligature in the wound.

B. FOLLOWING A BULLET-WOUND.—The track is insignificant and practically aseptic. Should operation take place at once, as soon as the wound is seen and a hæmatoma diagnosed? Or should the patient be kept under observation to allow an aneurism to form?

Many surgeons are in favour of the later operation, and affirm that it has many advantages. In proportion as the hæmatoma grows older and retracts, it diminishes in volume. The arterial or arterio-venous aneurism in which it ends is much smaller than the original hæmatoma, and is therefore more easily accessible. As cicatrisation proceeds the wound becomes healthier, and, most important of all, the collateral circulation is gradually established, until finally it constitutes a blood-supply which renders obliteration of the main artery of no importance.

Other authors, on the contrary, are in favour of early operation, the advantages of which are as follows: It is the sole safeguard against complications which may arise during the progress of the wound, such as sudden enlargement or septic infection of the hæmatoma. Contrary to expectation, it

is much less difficult than a delayed operation. The danger to the circulation of the limb is also less, for the wounded vessel is tied immediately above and below the wound, and no collateral branch is damaged. Delayed operation, on the other hand, involves the extirpation with the aneurism of a vascular segment, which may include one or more important collaterals. Lastly, by evacuating the hæmatoma and preventing the formation of fibrous tissue round the bleeding point, which leads ultimately to the development of an aneurismal sac, early operation constitutes the best prophylactic measure against venous compression, and especially against secondary nerve lesions, which, as we know, so frequently darken the prognosis in operation for aneurism.

For my own part, I am convinced that it is best to operate immediately on small hæmatomata as on large ones. The object here is not, as in the case of large or septic hæmatomata, to prevent ischæmic or septic gangrene, infection or secondary hæmorrhage; it is to anticipate from the first all possible complications. Moreover, and this is a very important point, early operation upon a small arterial hæmatoma is easier, more certain, and less dangerous than the later operation upon an arterial or arterio-venous aneurism.

The practical problems of treatment are as follows:—

1. *Primary operation.*—A patient is brought to a front-line station with a perforating bullet-wound of a limb. The orifices of entrance and exit are so situated that it is almost certain that the track of the bullet crosses the line of one of the main vessels, and examination reveals the existence of a medium-sized or small hæmatoma. In spite of the insignificant and

aseptic nature of the wounds, and in spite of the absence of risk of gangrene, is it necessary to expose the vessels at once by means of a special incision and treat the vascular wound directly? Yes, without a doubt.

The operation is identical with that described above. The first steps are to secure preliminary hæmostasis by digital compression above the wound, or by exposing the artery and passing a temporary ligature; then to expose the hæmatoma by a suitable incision, opening it freely and laying bare the wounded vessels. The operation is completed by the careful exposure of the vascular lesion and the establishment of permanent hæmostasis. In wounds of this class the risks of ligature are reduced to a minimum. The arterial lesion is generally clean, and only slightly contused. The thrombus in the proximal part of the vessel is small, consequently there is little risk of intravascular obliteration of the collateral branches. Further, as the hæmatoma is not large, and the collaterals are scarcely compressed at all, there is every chance of complete restoration of the circulation. Finally, the wound is aseptic and may be closed safely, the risk of secondary inflammatory swelling, which might interfere with the resumption of the circulation, being negligible.

It is, however, essential that the result of ligature should be ascertained beforehand by means of the tests given above. Should there be any suspicion of the possibility of gangrene, lateral or circular suture should be performed.

The suture of the skin and the insertion of a small drainage tube at the most dependent part completes the operation.

2. *Secondary operation.*—The case here is no longer that of a fresh wound or an injury a few hours or a few days old. These are subjects in whom the vascular wound has been overlooked, or in whom the hæmatoma has formed slowly and gradually, and who are brought to a base hospital two or three weeks or more after the wound has been received. The openings have cicatrised, but the course of the bullet is marked by a more or less extensive swelling, presenting all the symptoms of an arterial hæmatoma. The phrase arterial hæmatoma is deliberately employed, for the word "aneurism" is at this stage most misleading. The sac has no distinct wall, this so-called tumour is not extirpable, and it is not amenable to the treatment of true aneurism. In its present stage the hæmatoma is best treated by the operation which we have just described, namely, incision of the sac followed by direct hæmostasis in the wound.

Here again the first step, after securing temporary hæmostasis, consists in the thorough opening-up of the sac by suitable incision and exposure of the wounded vessel. I would draw attention to some important particulars. The sac contains very little fluid blood; it is filled with black clots like grapes, which are carefully removed by means of a swab, and sometimes with the curette. When the clots are removed there is no longer any sac; there is only a cavity between the muscles, the walls of which fall together, and at the bottom of which the wounded vessel is found. It is sometimes difficult to distinguish it among the blackened tissues stained with the colouring matter of the blood. At last a small bluish-white patch is seen, limited in extent, showing

up distinctly against the black colour of the surrounding tissues. That is the arterial endothelium, and the wound of the vessel is now easily recognised. The artery is isolated, tied or sutured, and the operation is finished. The wound in the artery is generally detected easily, because the lower end, which brings the blood from the collaterals, continues to bleed. When there is doubt, this sign may be accentuated by momentarily relaxing the compression above the wound.

Thus the treatment of arterial hæmatoma following on a bullet-wound is by incision of the hæmatoma and direct hæmostasis of the vascular wound. This operation should be performed as soon as the hæmatoma is diagnosed, whether at the field ambulance the next day, or at the base hospital two, three, four, or five weeks later if it has only then been recognised.

For how long may the arterial hæmatoma be treated by direct incision? In other words, for how long does it remain without a rigid, detachable wall of its own, which, when it is removed, leaves a gaping cavity, into which the neighbouring collaterals continue to bleed? As previously stated, this varies with the vessel, with its calibre, and with the extent of the original effusion. As a general rule it may be admitted that for the first six weeks the hæmatoma has no wall of its own, and may be treated by direct incision. From that time onwards the possibility of finding a well-formed aneurismal sac, which cannot be treated by simple incision, progressively increases.

It must not be imagined, however, that time, although important, is the only guide to treatment.

Arterial hæmatoma and traumatic aneurism are distinguished by their clinical features. Hæmatoma is diffuse, without exact limitation, and is not a separate entity; a traumatic aneurism, arterial or arterio-venous, is an isolated tumour, well defined, and with remarkably distinctive clinical features. I shall shortly describe the therapeutic indications of these unrecognised or unoperated-upon sequelæ of vascular lesion, arterial and arterio-venous aneurism.

III. Wounds of Arteries without Hæmorrhage

There is little further to be said in regard to the treatment of wounds of arteries that do not bleed. When the injury is due to a fragment from a large projectile, the arterial wound will be a chance discovery during operation by the surgeon of the ambulance who first sees the patient. Recent experience has removed all doubt as to the necessity of immediate operative treatment for all shell-splinter-wounds; preventive incision has become the rule in all surgical units at the front. Where the femoral, the posterior tibial, or the brachial has been injured by a splinter which remains impacted in the arterial wound, the splinter will be detected in the course of the prophylactic incision. Properly performed, this operation should expose the whole of the traumatised area; it should include the discovery of the missile and lay bare all the ramifications of the wound, no part of which should remain unexplored. Under these conditions it is impossible for the wound of the vessel to be overlooked. As soon as the clot, the shreds of clothing, and the missile are removed, a jet of blood spouts suddenly from the bottom of

the wound and reveals the position of the arterial injury. Its diagnosis constitutes the first stage of the treatment. While an assistant ensures hæmostasis by pressure above, the surgeon wipes out the wound; he then explores it, exposing the vascular lesion, which he treats by one of the methods already described. When compression above the wound is impossible, the artery is exposed above the wound and its lumen obliterated by raising it on a thread, an assistant tightly plugging the wound meanwhile. Not until hæmostasis has thus been secured should the tampon be removed and the wound in the vessel sought for. The directions given for the treatment of hæmatomata are applicable to these cases.

When, on the other hand, the wound is caused by a bullet, or by a minute shell-splinter, the orifice of entrance is punctiform, the track insignificant, and no hæmatoma is present. In such a case the wound in the vessel is almost certain to be overlooked at the first examination. That the flesh-wound is situated near the course of a large vessel is obvious, but in the absence of any hæmorrhage, external, internal, or interstitial, how is a vascular wound to be suspected?

Early diagnosis is, however, possible when the companion vein is wounded simultaneously with the artery, the edges of the venous wound becoming adherent to those of the arterial opening, a primary aneurismal varix being thus formed. The characteristic thrill may be discovered by chance when the hand is laid on the wounded region, and the diagnosis of vascular lesion is then plain. This is, however, quite exceptional, and at a first examination the thrill

may be easily overlooked. An experience such as Broca's may fall to the lot of even the most careful surgeon. While examining a patient he drew the attention of his assistants to the fact that, by some happy chance, the vessels in the track of the bullet had remained uninjured. A few days later the thrill characteristic of a double vascular lesion made its appearance. Thus, in the vast majority of cases, dry arterial wounds, whether by bullet or by minute shell-fragments, escape detection both at front-line stations and at base hospitals. It is not until later that certain minor functional troubles, in association with a small aneurism or an aneurismal varix, make their appearance. The patient, who has been returned to his regiment, finds himself eventually, with a history of vague functional trouble, in the hands of the regimental doctor. It frequently happens that the discovery of an aneurismal varix is entirely fortuitous, made during examination upon quite another count in a patient entirely unconscious of his vascular lesion. It is chiefly their remoter consequences which render these wounds interesting to the surgeon.

The treatment at the ambulances of hæmatomata, whether large, medium, or small, has now been described, together with the various problems of treatment which present themselves in the course of unrecognised or untreated vascular wounds, as well as the treatment of secondary hæmorrhage. We have still to consider the management of the remoter consequence of untreated vascular lesion, namely, traumatic aneurism.

Traumatic aneurism is either arterial or arterio-venous.

I. Arterial Aneurisms

1. THERAPEUTICS.—The usual course of arterial aneurisms is regularly progressive. The circulatory and nervous disturbances which they cause become gradually more accentuated, and in the course of this slow evolution various complications may suddenly occur which endanger life and limb.

Some cases of spontaneous cure have, however, been recorded. In these the circulation in the sac gradually becomes slower, the fibrinous clots being deposited in concentric layers on the wall, leaving only a narrow channel in the centre, which in its turn is finally obliterated, so that nothing is left of the aneurism but a small fibrous tumour without expansion, pulsation, or bruit. Since the commencement of the war cases of arterial aneurism presenting signs of spontaneous recovery have been shown at the Societe de Chirurgie by Pozzi, Routier, and Walther. Such a favourable termination must, however, be regarded as a fortunate exception.

As a general rule the symptoms become gradually more pronounced, the nervous troubles in particular becoming very much intensified. The increasing and repeated compression of the nerves adjacent to the sac or enclosed within its walls induces neuritis, accompanied by the appearance or the exacerbation of very acute pain, with signs of paralysis and anæsthesia and with trophic disturbances. The limb tends to become more and more powerless and painful.

The slow development of the symptoms is, unfortunately, only too frequently hastened by the occurrence of serious complications. These are rupture and inflammation of the sac.

Rupture of the sac is due to the progressive attenuation of its walls consequent upon its steady enlargement. Rupture may occur under the influence of the slightest shock or effort, sometimes without apparent cause. It may take place externally, into a neighbouring serous cavity, such as the pleura or the peritoneum, or into the cellular tissue, causing either serious external hæmorrhage, internal hæmorrhage, or diffuse secondary hæmatoma. In the two first cases death ensues rapidly. In the third, all the complications associated with a large diffuse hæmatoma immediately appear, the most rapid of which is ischæmic gangrene of the limb, due to sudden compression of all its blood-vessels.

Inflammation of the sac is favoured by the compression of the external tissues. Owing to compression, the vitality of the skin and cellular tissue becomes impaired, with the result that these tissues are susceptible to the slightest infection induced by cutaneous excoriation, however minute. The subcutaneous infection is conveyed to the aneurism, the clots putrefy, and the aneurismal wall softens. A suppuration, either circumscribed or diffuse, now develops, the sudden opening of which results in copious external hæmorrhage.

Finally, apart from rupture or inflammation of the sac, serious complications may occur as the result of *embolism*. Particles from the interior of the aneurismal sac are projected into the efferent artery, which they block, with the result that a gangrene, generally dry, is set up, the extent of which corresponds with the calibre of the obliterated artery.

The gravity of the prognosis in arterial aneurism demands active methods of treatment. We shall

now consider the measures to be employed and the indications for each.

2. METHODS OF TREATMENT.—According to Quénu and Muret, there are to-day three principal methods of treating arterial aneurism :—

1. Promotion of the spontaneous obliteration of the sac by coagulation of its contents.

2. Complete extirpation of the aneurism.

3. Cure of the aneurism without removal of its wall.

FIRST METHOD.—This includes all the methods of procedure, from acupuncture and ignipuncture to indirect compression and ligature of the artery in continuity above and below the sac, which act directly or indirectly upon the aneurism, and are designed to bring about coagulation of the blood.

A. *Compression.*—I shall do no more than merely mention *indirect compression* of the artery above the aneurism. It is carried out by means of a tourniquet, a leaden pad, or preferably the fingers. During the last twenty years its employment has become gradually less frequent. Out of 410 cases examined by Monod and Vanverts in 1911, compression was employed in only 19, that is, in 4·6 per cent. Of course, excluding the risk of complications, such as embolism and gangrene, the method is seldom efficacious. According to Monod and Vanverts, in more than half their cases it had no influence on the progress of the aneurism.

B. *Ligature.—Proximal ligature of the artery* has for its object the reduction of the circulation in the aneurism. This facilitates the formation of clots, thus favouring spontaneous recovery. Whether carried out immediately proximal to the aneurism

or farther away, at the most favourable portion of the artery (Hunter), the operation is simple and easy. Its simplicity is its only recommendation, while its disadvantages are many. It may be completely useless, as in cases where the aneurism has developed on a secondary branch in the neighbourhood of the main trunk and has been mistaken for an aneurism of the trunk. It is often inefficient, because the circulation is so well maintained by the collateral branches between the ligature and the upper pole of the aneurism that the desired object is not attained. It is obvious that this will happen more frequently after the Hunterian ligature than after Anel's. Even where the method is successful, where circulation is retarded, coagulation takes place, and the growth of the tumour is arrested, the effect upon the functional derangement is very slight. This applies especially to the nervous disturbances, the pain, paralysis, anæsthesia, and trophic derangements, which disappear only with the fibrous sac which compresses and alters the nerve-trunks. It is not surprising, therefore, that the number of failures is great. According to statistics based on 138 cases treated by this method Monod and Vanverts gave 12 per cent. of failures, but this is probably less than the real percentage.

Ligature above the aneurism, however, is not only ineffectual, it is often dangerous. I do not allude to the operative mortality, which ought to be very small if the operation is performed carefully and aseptically. The 7 per cent. of deaths mentioned by Monod and Vanverts is a very large proportion, and is dependent upon the fact that many of the cases quoted were old aneurisms. I refer only to gangrene

of the limb, which is comparatively frequent after ligature, more so than after extirpation. This is due to the fact that the ligature suppresses not only the circulation in the aneurism, but also that in certain of the collaterals, between the ligature and the sac. These are more numerous the higher the ligature is applied. Other factors are supplied by the presence of the tumour, which, after ligature, may compress the collateral vessels, and by the frequency of embolism. In the latter case, particles of the clots in the sac are driven into the distal part of the artery by the blood coming from a collateral. These causes of gangrene occur independently of surgical asepsis and of operative efficiency. It is not to be wondered at that the proportion of cases of gangrene after ligature has only very slightly diminished in the last twenty years. In 1895 Delbet quoted it at 8·25 per cent. In 1910 Monod and Vanverts found the percentage to be 6·5.

I shall say nothing about *ligature in continuity distal to the aneurism*, either quite close to the lower pole of the sac (Brasdor) or at a distance (Wardrop). These are makeshift methods dictated by necessity, and employed only in certain aneurisms at the root of the neck, in which proximal ligature is extremely difficult and hazardous.

SECOND METHOD.—The second method, which consists in *extirpation of the aneurism*, is the one most generally employed in France and in Europe generally.

As the first step in the operation consists in exposing the artery immediately above the tumour, preliminary hæmostasis is not necessary. A longitudinal incision is made over the surface of the tumour,

supplemented, where necessary, by one or more transverse incisions, or a flap, which may be cutaneous, musculo-cutaneous, or osteo-cutaneous. When the tumour is exposed, its proximal pole is dissected out and freed as much as possible from the surrounding parts until the afferent vessel comes into view. If the artery is on the anterior wall of the aneurism, it will be found easily, and quickly exposed; when it is on the posterior or lateral wall of the sac, exposure is a longer and more difficult matter. As soon as the artery has been exposed, it should be caught in an artery-clamp. At the distal end of the tumour the same process of dissection and separation is then carried out, the efferent artery being exposed and clamped.

The next step is to dissect out the proximal half of the sac by separating it from the arterial trunk from above downwards. In the course of this manipulation the branches given off from the principal trunk are encountered. These are applied closely to the sac, and often open into it. They should be tied at their origin. The proximal half of the aneurism being now freed, the distal half is dissected in a similar manner, working from below upwards. Its outer surface is very carefully separated from the nerve-trunks which lie along it, and which are adherent to it or closely embedded in it. Sometimes they have to be actually carved out of the fibrous sheath surrounding them. The tumour is now completely isolated, and is retained only by a slender pedicle, where the main artery opens into the aneurism. This pedicle may be extremely slender, or it may be more than an inch in width. Occasionally the isolation of the aneurism is extremely difficult; in

such a case the sac should be opened and dissected out like an adherent hernial sac, one or more fingers being introduced into its interior. When the tumour is completely freed, it is excised close to its attachment to the artery; this may involve the resection of half an inch or more of the vessel.

We are now faced with a loss of the arterial wall. which may be either lateral or circular. It is only necessary to apply a permanent ligature to each end of the artery, and the extirpation of the aneurism is completed (figs. 37 and 38).

FIG. 37.—Extirpated aneurism of the brachial artery. (Professor Jacob's case. Val-de-Grâce Museum.)

The repair of the vessel may also be attempted by lateral or circular suture or by venous transplantation. A fine continuous suture, supplemented, where necessary, by a few interrupted ones, will close a lateral opening in a few minutes. The entire circumference of the vessel may be repaired in ten or twelve minutes by a triple row of continuous suture after Carrel's three supporting threads have been applied. Finally, if the two ends of the artery are not sufficiently close together to permit of a circular suture, a segment from the trunk of a neighbouring vein may be grafted into the gap.

Which is the preferable method of these two?

Extirpation followed by double ligature is a method which may be regarded as innocuous. Apart from

avoidable septic complications, the mortality is almost nil. According to Delbet, 86 cases were published between 1887 and 1895, and these did not include a single death. Between 1895 and 1911 205 cases were published, and of these only 7 terminated fatally—a mortality of rather more than 3 per cent.

FIG. 38.—Arterial aneurism of the ulnar, extirpated at the moment of rupture. (Professor Jacob's case. Val-de-Grâce Museum.)

The method is also very efficient. To borrow Delbet's phrase, extirpation of an aneurism effects a radical cure, for the patient is permanently relieved of his aneurism and of all the disturbances resulting from it.

Extirpation, unfortunately, presents one weak point, and that is the possibility of gangrene. Among the 205 cases collected by Monod and Vanverts, there were 9 cases of gangrene, or 4 per cent. Out of 93 cases which I have found in French and foreign publications since the war begun, there were 9 cases of gangrene, or about 10 per cent. Of these 9 cases, 2 were of gangrene after extirpation of an axillary aneurism, 4 after extirpation of a femoral, and 3 after extirpation of a popliteal aneurism. From these observations, which were confined to aneurisms from war-wounds, gangrene followed extirpation of an

axillary aneurism in 11 per cent. of cases, of popliteal aneurism in 13 per cent., and of femoral aneurism in nearly 30 per cent. of cases.

What is the practical conclusion to be drawn from these facts? That, in the case of all the larger arteries, the axillary, femoral, popliteal, etc., the permeability of the vessel must at any cost be re-established? Where there is no risk of gangrene, such a procedure provides only an unnecessary complication. The essential point is to ascertain beforehand whether, in the particular case under consideration, gangrene is to be anticipated or not. Is this possible?

Valuable information is yielded by pre-operative examination. The presence of rigid, non-elastic arteries in an elderly soldier is an unfavourable prognostic sign. If the circulation in the aneurism is strong, the expansile pulsation very marked, and the bruit loud and harsh, it is certain that the principal artery is still the chief source of the blood-supply, and that the collateral circulation is consequently only slightly established. If the peripheral pulse-beat is as strong as that of the opposite side, the inference is the same. All these signs are, however, vague and uncertain, and more definite data are required. Korotkoff has suggested compression of the vessel above and below the tumour, thus realising the conditions obtained by ligature, and observation by means of the manometer of the variations of blood-pressure in the extremity of the limb. If the peripheral pressure falls roughly to zero, gangrene is probable; if there is no change, gangrene will not occur. The theory is sound, but experience has shown that the method is not reliable in practice.

It is often extremely difficult to produce a degree of compression above the tumour equal to that of ligature.

It is expedient in this connection to recall certain clinical features of arterial hæmatoma. In a former chapter it was shown that when the collateral circulation is sufficient, the extremity of the limb is only slightly affected by a temporary ligature above the tumour. When, however, the collateral circulation is insufficient, the limb turns pale and cold. If the blood is circulating in the limb, compression of the accompanying vein induces a swelling of its peripheral end. Finally, an oozing of blood or a hæmorrhage on the temporary removal of the clamp from the lower end of the divided artery shows that the collateral circulation is established. In specially doubtful cases a small incision, in the tip of one of the digits, for instance, will show whether the circulation is maintained. This combination of methods will furnish sufficiently reliable evidence of the presence or absence of the collateral circulation and the consequent chances of gangrene.

I must not, however, omit to state that the presence of a collateral circulation which is sufficient to prevent gangrene may not be enough to ensure the proper working of the limb. It is well known that the amount of blood required for the preservation of life in the tissues and organs is much less than the amount necessary for the active function of these organs, especially of the muscles. This applies equally in the case of the collateral circulation. That is no doubt the reason for the permanent powerlessness, sometimes complete, which follows the extirpation of some aneurisms. It is undoubtedly an

additional reason for caution in the employment of the double ligature after extirpation of the sac, even in cases where gangrene is not probable.

Thus in a certain number of cases it is unfortunately impossible to determine beforehand whether ligature of both ends of the artery after extirpation of the aneurism will be followed by gangrene of the limb, or at the least by such an impairment of its circulation that function is permanently reduced. On principle, therefore, wherever possible, an attempt should be made to prevent these complications by restoring the permeability of the vessel by lateral suture, circular suture, or even venous transplantation.

In 1911 Monod and Vanverts knew of only two cases of circular suture and two of venous grafting after extirpation of an arterial aneurism. The number of such operations has, however, greatly increased since the war. Soubbotitch has described thirteen cases of arteriorraphy performed by him in arterial aneurism. In eight cases he employed lateral suture. Of these, four were successful; three were unsuccessful, one ending in death; in one case the result was unknown. In five cases he employed circular suture with success. He also reports eighteen further cases of traumatic aneurism due to projectiles, ten of which were treated by lateral and eight by circular suture. Gangrene followed in four cases. Bonin has recently described twelve cases of arterial and arterio-venous aneurism, in eleven of which operation was successful, and in one, a circular suture of the internal carotid, the termination was fatal. The eleven successful operations comprise one lateral and ten circular sutures, six of which were accompanied by venous

transplantation. All these results are interesting. Although owing to certain technical difficulties vascular suture does not absolutely ensure the permeability of the vessel, it must be regarded as the ideal method in doubtful cases, which should always be attempted before recourse is had to permanent double ligature.

THIRD METHOD.—The third or American method of *aneurismorraphy* (Matas) consists in opening the sac, examining its internal surface, and adopting procedures which vary in accordance with the conditions present.

When incision of the sac reveals only one arterial orifice which communicates with both the central and the peripheral ends of the artery—in other words, when the aneurism is saccular, arising, so to speak, from a lateral orifice, this orifice should be closed by bringing the endothelial surface of the walls together and uniting them by one or more rows of sutures. The artery is thus shut off from the sac, and the continuity of the vessel is preserved. The sac is coapted by a few mattress sutures. This is the operation known as *reparative aneurismorraphy*, the ideal method in sacculated aneurism.

A sac may be found to contain several openings, or it may have two long orifices corresponding to the afferent and efferent ends of the artery. In the latter case the aneurism is fusiform in shape, and corresponds to a kind of dilated tube which replaces a segment of the artery. There are two possible methods of treatment. Both openings may be closed by suture, in the manner adopted for the single opening in the operation described in the preceding paragraph. This results naturally in the

complete obliteration of the vessel; hence the operation is termed by Matas *obliterative aneurismorraphy.* Or the internal wall of the sac may be sutured round two sounds, which are introduced respectively into the central and peripheral ends of the vessel and are removed as the last stitches are being put in. This operation results in the formation of a narrow channel joining the two ends of the artery, and is known as *reconstructive aneurismorraphy.*

The advantages of the American method are its simplicity and the facility of its execution. As a general rule the free incision of the aneurism is better than a long and difficult external dissection, for it allows the relations of the aneurism with the vessel to be at once perceived.

After the aneurism has been opened, it has been the custom until recently to perform obliterative aneurismorraphy. The method is not obviously superior to extirpation followed by double ligature. On the contrary, it possesses certain distinct disadvantages, due to persistence of the aneursimal sac, and the clinical results are less satisfactory than those of extirpation.

The only really valuable method of treating traumatic aneurism is that of reparative aneurismorraphy. This is a conservative measure, which possesses the advantages of repair of the vessel without the difficulties inseparable from vascular suture after extirpation of the sac. I have performed the operation on one occasion only, and must in fairness admit that it is not always easy. The tissues are hard and friable, and the accurate insertion of the sutures may be extremely difficult. In spite of its difficulty, however, the operation is a very attractive one. In

1911 it was employed nine times in popliteal aneurism with complete success (Quénu and Muret).

Summary.—Of the three principal methods of treatment of traumatic aneurism, the classic operation is still extirpation of the sac, with ligature above and below. The ideal method, however, is the re-establishment of arterial continuity by lateral or circular suture, with or without venous transplantation. The method can no longer be regarded as exceptional; on the contrary, it represents a perfectly—one might almost say easily—attainable ideal. The method should always be employed in the case of a dangerous artery and in cases where there is the slightest reason to anticipate gangrene. In spite of its attractiveness, Matas' operation is not of capital value. It is perhaps preferable to extirpation with double ligature, but in view of the fact that it leaves embedded in the tissues a fibrous sac which is occasionally inflamed, it is certainly less advantageous than extirpation followed by immediate repair of the vessel.

II. Arterio-venous Aneurism.

1. THERAPEUTIC INDICATIONS. — Arterio-venous aneurism is far slower and more insidious in its development than arterial aneurism. Months, even years, may pass without an appreciable change in the size of the tumour. Occasionally, though this is exceptional, it diminishes in size; the thrill, expansion, and murmur disappear, and spontaneous recovery takes place. Since the outbreak of war both Pozzi and Routier have shown patients before the Société de Chirurgie who, six months previously, had presented all the signs of arterio-venous aneurism in

the neck. The sole treatment was by rest, yet the tumour, with all its manifestations, thrill, expansion, and murmur, had completely disappeared.

Such instances are, however, rare. As a general rule the tumour persists and, in the long run, produces a varying degree of derangement of the circulation of the limb as well as of that of the heart. The circulatory disturbances are manifested by more or less marked dilatation of the veins below, by œdema, cyanosis, and pain. The pain and œdema are occasionally so intense as to suggest phlebitis. These signs are frequently accompanied by nervous symptoms of varying intensity, such as hypoæsthesia with numbness and paresis of the limb. In exceptional cases the nervous symptoms are sufficiently intense to interfere with the functional activity of the limb. It is very important that the cardiac symptoms should not escape detection, and that their real origin should be recognised. The sudden and rapid return to the right heart of blood projected by the axillary or femoral artery into the central end of the companion vein is accompanied by considerable disturbance of right cardiac function. This is a point which has never been sufficiently emphasised. I consider it one of the chief indications for surgical treatment of the aneurism. I recently operated with Cotte upon a case of arterio-venous aneurism of the hypogastric (internal iliac) vessels, in which the cardiac symptoms, namely, palpitation, dyspnœa, and painful tachycardia, were extremely marked.

Complications are rarely associated with the development of arterio-venous aneurism. Rupture and infection of the sac are quite exceptional; they never occur except in cases where, as the result of fortuitous

obliteration of the venous orifice, the arterio-venous aneurism becomes converted into an arterial aneurism.

The freedom of certain cases of arterio-venous aneurism from grave complications and threatening symptoms furnishes a contra-indication to surgical intervention. These are cases in which an aneurism, which provokes only minor circulatory and cardiac disturbances, is situated in a region which is difficult of access; in these the risks of operation are not counterbalanced by the clinical results. Aneurism at the base of the neck and abdominal and pelvic aneurisms are examples of this. Where, however, the cardiac and circulatory disturbances are very marked, immediate surgical treatment is unconditionally indicated.

2. TREATMENT.—Having established the fact that the grave symptoms, namely, those of the heart and circulation, are due to the direct passage of the arterial blood into the central and peripheral ends of the vein, the object of all methods of treatment of arterio-venous aneurism is the complete and permanent separation of the two currents of blood and the obliteration of the vascular anastomosis.

Anastomosis is sometimes direct (aneurismal varix), sometimes indirect (varicose aneurism). In reality this distinction is more apparent than real. It is true that a simple aneurismal varix has not, in the true sense, a sac; but the central and peripheral ends of the vein are sometimes so distended that they form an actual pocket at the site of anastomosis. Moreover, the slow inflammation of the neighbouring tissues produced by the repeated impulses from the blood-stream causes them, as in varicose aneurism, to become adherent to the external walls of the

dilated vessels. The two vessels, anastomosis of which is sometimes minimal, and does not exceed 2–3 mm. in diameter, are externally adherent well beyond the limits of anastomosis. Consequently, from the point of view of the operative separation of the two vessels, aneurismal varix presents very similar conditions to those of varicose aneurism. In both classes of case, separation is obtainable only by ablation of the anastomosed arterio-venous segment.

In aneurismal varix the ideal operation is the separation of the artery and vein by ligature of the little canal which unites them; or, where the canal is very short, by separate lateral suture of both artery and vein.

In varicose aneurism the ideal operation is extirpation of the intermediate aneurismal sac, and repair by appropriate suture of the two vessels.

Since the outbreak of war the number of arterio-venous aneurisms treated by ideal methods has rapidly increased. In 1911 Monod and Vanverts knew of only ten cases in which the ideal method was attempted, and in three of these the reparative measure was confined to the vein. Since the war, Soubbotitch has reported nineteen cases of angiorraphy for arterio-venous aneurism to the Société de Chirurgie, of which fourteen were successful, one partially successful, in two suture was unsuccessful, one result was unknown, and one ended in death. Bonin has published nine cases, seven by Hotz and two by Geiger. Makins has described an angiorraphy performed by him in arterio-venous aneurism of the femoral. Individual cases multiply on every side. The cure of arterio-venous aneurism is no longer the

exceptional outcome of unusual technical skill. It is attainable by ideal methods, which are accessible to everyone familiar with the surgery of the vessels. These methods should always receive consideration when operation upon arterio-venous aneurism is undertaken.

Unfortunately the operation is not invariably applicable. In the case of varicose aneurism, the close adhesion of artery to vein, and of both to the surrounding tissues, renders the isolation and separation of the vessels frequently impossible. In the case of aneurismal varix, the fusion of the sac with the tissues and organs which surround it frequently renders total extirpation impossible; or it necessitates the resection of so considerable a vascular segment, that the vessel is no longer amenable to repair. In such cases recourse is had either to quadruple ligature, obliterating both artery and vein above and below the anastomosis, or to extirpation of the sac with ligature of all the vessels involved.

Quadruple ligature is a comparatively simple and easy operation. It may, however, present considerable difficulty when the arterio-venous lesion is situated in the neighbourhood of a tributary vein, the jugulo-subclavian junction, for instance. In order completely to separate the two vessels it is sometimes necessary in such a case to ligature the innominate artery and the subclavian and jugular veins as well as the carotid.

The method, moreover, presents certain grave drawbacks. It may under certain conditions prove both dangerous and ineffectual. It is ineffectual where the arterial and venous branches open into the sac or into the vascular segment between the ligatures.

The venous collaterals continue to drain the collateral arteries, and the very conditions which operation was intended to relieve continue to exist. Thus all the local signs of aneurism either persist or rapidly reappear. The method is dangerous where the collateral veins leading away from the sac or isolated vascular segment carry off the entire quantity of the arterial blood supplied to it by the collateral arteries, thus preventing their participation in the peripheral irrigation of the limb. Such conditions are eminently favourable to the development of gangrene. A case of von Oppel's, which has frequently been quoted, is very instructive in this connection. The case was one of arterio-venous aneurism in the axilla. Von Oppel ligatured the artery above the aneurism, and then measured the peripheral blood-pressure by Korotkoff's method. The pressure before ligature was 40 mm.; after ligature it fell to zero, proof positive that the whole of the blood supplied by the collateral circulation was conveyed back towards the heart by way of the vein. Two hours later he ligatured the vein above the sac. The peripheral pressure remained at zero, proving incontestably that the sac was still in communication with a large venous channel. Examination revealed a large vein at the back of the sac. This was tied, when the blood pressure again rose to 40 mm.

The extirpation of the sac with ligature of all the vessels which open into it is a longer and more difficult operation than that of quadruple ligature. It is, however, far more effectual, and, judging by accounts published before the war, it is considerably less dangerous. Out of 167 cases of partial or total extirpation, Monod and Vanverts found 110

successful, or 95 per cent. Gangrene occurred in two cases, or 1·7 per cent. It will be shown later, when considering arterio-venous aneurism of individual vessels, that these results are confirmed by those obtained since the outbreak of war.

It is unnecessary, after what has been said concerning quadruple ligature, to enter into the details of the old methods, namely, compression and ligature of the artery proximal to the lesion. These methods are not only effete, they are ineffectual and dangerous.

Thus, apart from the ideal reparative operation, the most suitable method of treatment of arterio-venous aneurism is undoubtedly that of extirpation of the anastomotic segment, with ligature above and below of all the afferent and efferent vessels involved. The technique of the operation is as follows :—

The first part of the operation consists in the complete exposure of the aneurism and of all the vessels involved. It is hardly necessary to repeat that the area must be very thoroughly opened up. In the case of hypogastric aneurism referred to in a previous paragraph, Cotte and I did not hesitate to perform an extensive laparotomy. Having exposed the site, the next step is to ascertain the nature of the lesion, whether aneurismal varix or varicose aneurism, and if the latter, to discover the size of the sac.

In the case of aneurismal varix, the best method is to arrest the circulation by means of clamps applied to both vessels above and below the affected area. It is best to begin with the artery, applying a clamp to it first above and then below. The vein should not be clamped above until the last moment, for the sudden occlusion of the central end prevents the

discharge of the blood brought to the intermediate segment by the collaterals, with the result that the segment becomes enormously distended. The anastomotic segment is now dissected out, and the vein is separated from the artery as far as the point of communication. Where possible the communicating channel between the two vessels is ligatured. Where ligature is impossible, the channel is cut and the

FIG. 39.—Arterio-venous aneurism of the subscapular vessels. (Tixier's case. Val-de-Grâce Museum.)

resulting arterial wound closed by lateral suture. Suture of the venous wound is superfluous, as ligature above and below meets all requirements. Where this, the ideal, operation is not feasible, quadruple ligature must be employed, and the arterio-venous segment between the ligatures extirpated. Ligature above and below the anastomosis may require the application of five ligatures, as in the case of aneurismal varix affecting the venous tributaries or an

arterial bifurcation. Under such conditions, extirpation of the vascular segment may be impracticable.

In the case of varicose aneurism the tumour is first extensively exposed. Artery-clamps are affixed first to the afferent and efferent arteries, and afterwards to the veins. The tumour is then minutely dissected out and extirpated, together with the segments of both artery and vein involved (fig. 39). In view of the loss of vascular supply, the state of the collateral circulation should be ascertained by one of the methods described above. If it appears to be insufficient, the vein and its branches should be ligatured above and below, and circular suture of the artery should be performed. Or it may be necessary to introduce a venous graft between the two ends of the artery. Where the circulation appears to be adequate, double ligature of both artery and vein is indicated.

It sometimes happens that an aneurism becomes incorporated, by means of fibrous adhesions, with the surrounding tissues, and that its extirpation is impossible. In such a case the sac should be opened, hæmorrhage arrested, as much as possible of the sac resected, and the rest left in place.

CONTUSION OF THE VESSELS

CHAPTER III

ANATOMICAL AND CLINICAL STUDY OF CONTUSIONS OF THE VESSELS

RIFLE-BULLETS may, under varying conditions, cause contusion of an artery or a vein.

In certain exceptional cases a spent ball, or a ball which has been retarded by passing through a bone, may be arrested in contact with a large vessel, which is struck more or less violently but is not ruptured. More frequently an artery is struck tangentially, the ball encountering only the tunica externa or the perivascular fibrous sheath. In a few cases contusion of an artery is occasioned by the passage of a ball at some distance from the vessel.

Thus the mechanism of contusion varies. It may be the outcome of direct shock, as where an artery is struck by a spent ball. Direct shock is more frequent in association with wounds caused by shrapnel-balls than by bullets of small calibre. Contusion may result from hydraulic shock to the vessel, effected at the moment when the ball comes in contact either with it or with the tissues in its immediate neighbourhood. More frequently, however, contusion is due to the

elongation or stretching of the vessel. Elongation is responsible for subcutaneous arterial rupture, and it plays a preponderating part in the causation of vascular contusion by projectiles of war. Immediately after the passage of a bullet in the subclavicular fossa or the axilla I have more than once observed sudden and complete paralysis of the arm with suppression of the radial pulse. Immediate surgical intervention showed that neither ne nor blood-vessel was divided. In two of these cases the injured portion of the axillary artery appeared as a fine cord uniting the two sound portions. This stretching of the artery is well shown in fig. 40. The external iliac is divided by a bullet near its lower extremity. At two points above the wound the internal coats are ruptured by over-stretching.

Vascular contusion is more frequently caused by fragments of shell, grenade,

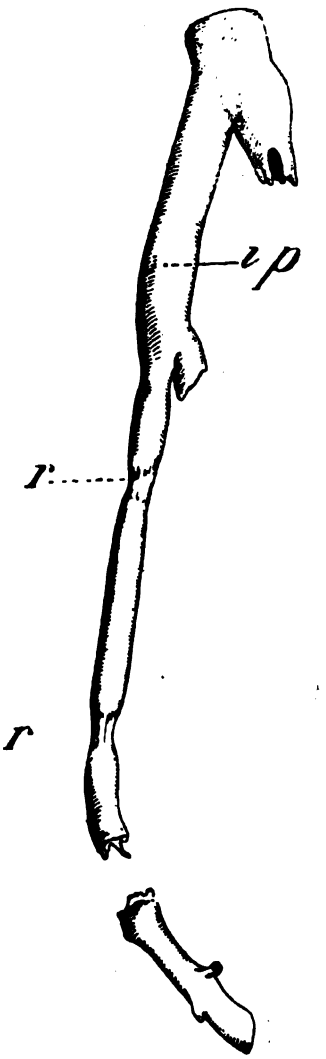

FIG. 40.—Section by a bullet of the right external iliac artery. Above the section the artery shows contractions due to rupture of the internal coats by over-stretching. Death ensued twelve hours after the injury. (Latarjet's case. Val-de-Grâce Museum.)

or torpedo than by bullets. Here again the mechanism of production is of three kinds: direct shock, indirect shock conveyed from a distance, and over-stretching of the vessel. Arterial contusion by a ball or shell-fragment is in many instances obviously due to either direct shock or elongation of the vessel. The missile has indeed been frequently discovered in actual contact with the injured artery. Grégoire has described a typical case of contusion of the posterior tibial, with rupture of its two inner coats, by a fragment of shell which was arrested at the posterior surface of the interosseous ligament. Cases of this description are far more numerous than is generally believed, and in many instances secondary hæmorrhage is attributable to this source alone. But indirect injury plays so large a part in the history of shell-wounds that it cannot fail to be responsible for a considerable number of vascular contusions. Shell-wounds are characterised by extreme contusion, which varies in degree from immediate and rapid gangrene at the site of injury to slight bruising at a distance. A vessel situated in the wall of a wound or very near it is contused in the same manner as the tissues by which it is surrounded. The degree of contusion varies with the volume and velocity of the projectile on the one hand, and its distance from the direct point of contact on the other.

PATHOLOGICAL ANATOMY AND PHYSIOLOGY OF CONTUSIONS OF THE VESSELS

The Val-de-Grâce school has taught us that three degrees of contusion are to be differentiated:

In contusion of the first degree the lesion affects the internal coat only. On opening the vessel " fine transverse striations are seen, which look as if produced by the point of a pin drawn over the surface of the vessel " (Delorme).

In contusion of the second degree both the internal and middle coats are injured. The fine lines upon the intima penetrate deeply into the media, the muscular and elastic fibres of which are ruptured here and there.

In contusion of the third degree the intima and media are ruptured circularly around the entire circumference of the vessel (fig. 41). They are retracted within the adventitia, and to so great a degree that, viewed externally, the artery presents a constricted appearance (fig. 40).

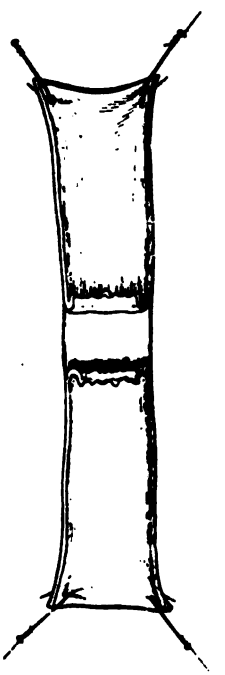

FIG. 41. — Diagram showing arterial contusion of the third degree. The internal and middle coats are ruptured.

These experimental findings have been confirmed by the results of surgical observation since the war.

Where it is the sole injury, contusion of the first or second degree is too slight a lesion to produce appreciable symptoms, or to point to any active treatment by operation. But as all vascular wounds by projectiles of war are contused wounds, it follows that even clean-cut arterial wounds are associated with contusion in a varying degree. When we have to deal with a wound of a large vessel exposed after provisional hæmostasis by

compression above the wound, the lumen of the vessel should be cleared of the remaining blood by the injection, very gently and without pressure, of a few cubic centimetres of physiological serum. The lacerations of the internal coat will then become visible over the entire circumference of the wound. They may start from the wound itself and radiate in all directions; or they may be situated at some distance from the wound, every stage of arterial contusion being represented. Fig. 42 shows a portion of the femoral artery which presents well-defined contusion of the second degree. The significance of these lesions in regard to the general indications for vascular suture was explained in an earlier chapter.

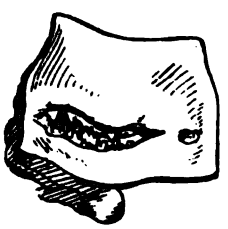

FIG. 42. — Contusion of the femoral artery by a shell-fragment. Resected portion of the artery, showing partial rupture of the internal and middle coats. (Latarjet's case. Val-de-Grâce Museum.)

Contusion of the third degree has been observed *de visu* in a certain number of cases. In some instances it appears as a narrow constriction corresponding to the site of retraction of the torn inner coats. More frequently, however, exposure reveals a species of fusiform dilation of the vessel corresponding to the contused portion, the wall of which is represented solely by the adventitia. In September 1914 a young lieutenant was brought into my ambulance who had been struck by a fragment of shell which had traversed the anterior wall of the axilla. The arm was cold, swollen, and insensitive. Incision of the anterior wall of the axilla and exposure of the vessels and nerves showed a fusiform dilation of the

axillary about 1½ inches long. The enlargement was of a doughy consistence, and did not pulsate (fig. 43).

The effect of these lesions upon the contents of the vessels varies considerably.

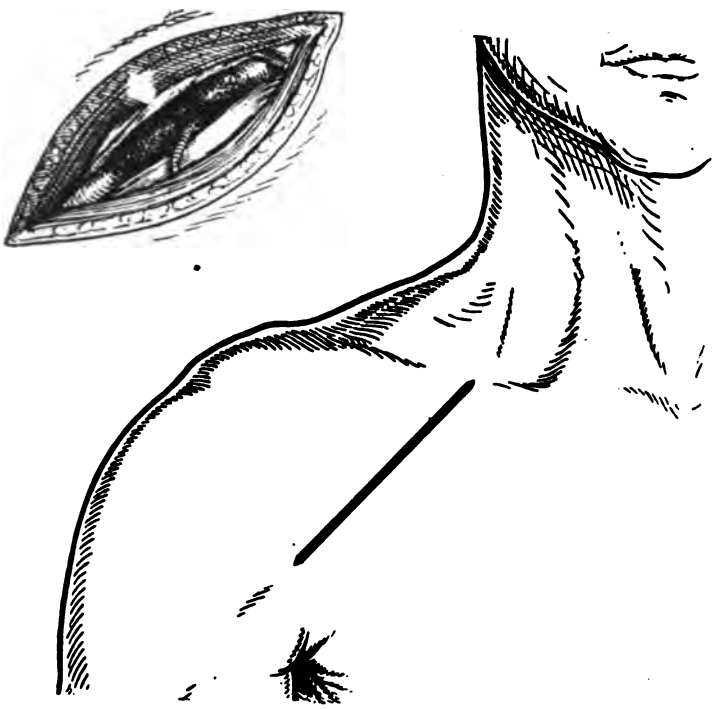

FIG. 43.—Contusion of the axillary artery by a shell-fragment. The contused arterial segment is dilated and thrombosed. (Author's case.)

The fine striation of the intima, which characterises contusion of the first degree, does not as a rule affect the circulation of the blood through the vessel. Contusion of the second degree is frequently accompanied by the formation of a thrombus. The thrombus may be lateral and very limited in extent, and it

may not occlude the lumen of the vessel. On the other hand, it may be extensive, obliterating the lumen of the vessel for a considerable distance and extending to the first, second, or even third collateral branch above.

A small parietal thrombus which does not obliterate the lumen of the vessel almost invariably escapes notice. The peripheral pulse is not suppressed, there is no circulatory derangement, and there are no signs suggestive of a vascular lesion. Even when the vessel is exposed to view there is no appreciable change in its external aspect. The presence of a thrombus is in such cases revealed only by the small emboli which proceed from it. A patient was brought to me with a shell-wound in the neck, but presenting no symptoms of vascular lesion. The wound was opened up and the vessels exposed. The common carotid and the internal jugular, which were in the immediate vicinity of the wound, were found to be intact. A few days later several successive embolisms occurred, giving rise to transient hemiplegia. There is no doubt that these emboli originated in a circumscribed thrombosis of the common carotid, which had been slightly contused by the passage of the projectile.

Complete thrombosis, obliterating the lumen of the vessel, may be confined to the contused area. On the other hand, it may extend for a considerable distance into the lumen. Grégoire describes a case of contusion of the posterior tibial with gangrene in which it was necessary to remove the leg. On dissecting the amputated limb he found a thrombus which extended from the contused site to the popliteus above and to the internal malleolus below. Throm-

bosis of this kind, as in the case described on p. 142, may present the appearance of a fusiform dilation of the artery several inches in length.

It is scarcely necessary to point out that contusion of the third degree, that is to say, sub-adventitial rupture of the internal coats, is invariably accompanied by arterial thrombosis. The blood coagulates above the constricted portion, and the clot extends upwards for a varying distance.

Primary thrombosis, the direct outcome of laceration of the internal coats, may be complicated by secondary thrombosis due to infection of the wound in the neighbourhood of the contused vessel. That simple denudation of the vessels under septic conditions facilitates the spread of infection to the vascular coats is known to everyone. This is particularly striking in cases where the vessels are exposed at the bottom of a tortuous and ill-drained wound, in which putrid fluid of a highly septic nature stagnates. Such wounds are frequently observed in the neighbourhood of the mouth and pharynx. Some time ago Morestin pointed out the danger of infection of the vessels of the neck when freely exposed at the bottom of a wound which is contaminated by the bucco-pharyngeal secretions. The danger is increased in cases where the arterial wound is contused, where the adventitia presents small erosions communicating with ecchymoses of the inner coats, and where there is circulatory disturbance of the vasa vasorum. Under such conditions infection is conveyed directly to the vessel, and there is an immediate increase in the size of the thrombus. Grégoire's case, in which the clot filled the lumen of the vessel from the soleus to the malleolus, is an excellent example.

Clinical Considerations and Treatment of Contusion of Vessels

Contusion of the first and second degree is not actually a clinical entity, for it does not present a syndrome of sufficiently definite outline to establish a diagnosis. The sole evidence of its presence is supplied by certain secondary complications which proceed from it. These complications depend upon the migration of clots from the thrombosed portion of the vessel. The emboli are arrested either in the cerebral vessels (Sylvian or ophthalmic) or in the peripheral arterioles of the limbs (toes, fingers). Embolism of the cerebral vessels results in hemiplegia or monoplegia, which may be either transitory or persistent. Embolism of the arterioles of the limbs is followed by the appearance of cutaneous sloughs, or even of dry gangrene.

In an earlier chapter I described a case in which a shell-wound in the neck, unaccompanied by vascular lesion, was followed by successive hemiplegias undoubtedly due to emboli derived from a contused patch in the vessels. Four cases have been described by Makins in which embolism followed thrombosis due to arterial contusion. In three of these cases there was contusion of the common carotid; in one of the three, brachial monoplegia followed; in the second, hemiparesis with mental derangement; in the third, aphasia terminating in death. In the fourth case the femoral artery was involved; an embolus obliterated the popliteal artery, and gangrene of the foot ensued.

Contusion of the third degree is attended by immediate results which, from the outset, present a com-

bination of very characteristic symptoms. Arterial thrombosis is constant and rapid. The extension of the clot upwards may at once obliterate the openings of the principal collaterals. The circulation, both in the main artery and in the collaterals which should replace it, is thus suddenly suppressed. Ischæmic gangrene of the portion of the limb supplied by the artery results.

Immediately after injury the limb presents a diffuse swelling below the level of the wound. The skin is pale, cold, and occasionally cyanosed. Palpation shows a generalised œdema of the limb. Cutaneous sensibility is lost, and motility of the limb is entirely abolished. Several cases of this type have been described since the war, and I have myself observed three. Makins describes five, with two primary amputations.

In a certain number of cases the thrombus is confined to the injured segment of the artery. It does not invade the branches above, nor does it at first entirely suppress the collateral circulation. Gangrene is excluded, but other complications may arise during the clinical development of the wound. The demarcation and subsequent elimination of the slough in the vessel may, in such cases, cause the wound to open into the lumen of the vessel. Again, the clot may become infected and soften, when secondary hæmorrhage, either single or multiple, will result, and death may follow very quickly.

Thus contusion of the first and second degree, having no actual clinical individuality, is practically never recognised during the first few days after injury. A retrospective diagnosis, based upon the appearance later of complications due to embolism, is the most

that is possible in these cases. It is obvious that where there is no diagnosis there can be no treatment.

Where ischæmic gangrene is present, contusion of the third degree may be diagnosed from the start. In the absence of gangrene it may at first escape notice, to be recognised later when secondary hæmorrhage is provoked by the separation of the slough in the vessel. The problem of treatment is not the same in the two cases.

In the first case we are faced with a shell- or bullet-wound in the neighbourhood of a large vessel. There is no external hæmorrhage and no hæmatoma. Yet the swelling of the limb, its pallor and coldness, and the absence of the peripheral pulse, together with the intense pain and marked functional derangement, immediately suggest a lesion of vascular or nervous origin. The fact has already been emphasised that in cases such as these primary surgical intervention is indicated. Operation should be immediate, the object generally being the discovery of a wound of the vessels, for the idea of a simple vascular contusion rarely occurs to anyone.

Exposure of the artery establishes the diagnosis. The presence of circumscribed constriction or dilation points to severe contusion with thrombosis. What is the method of procedure ?

Whatever the method, the end in view is the removal of the thrombus, which obliterates the lumen of the artery and threatens the collaterals. Its extension must in any case be prevented.

It has been suggested that, to prevent embolism, the artery should be ligatured below the clot. The method does not appear to me to be practicable. In the first place, it is extremely difficult to ascertain

the extent of the clot, and there is no certainty that the ligature is actually below it, and that embolism is excluded. In the second place, the great danger in thrombosis lies in the extension of the clot upwards and the obliteration of the collaterals. Ligature below does not in any way prevent this. As a matter of fact, ligature above and below is open to the same objections, for here also there is no guarantee that the ligatures have been placed outside the clot.

For these reasons the ideal method seems to be arteriotomy and removal of the thrombus, followed by double ligature. Longitudinal incision permits of the removal of the clot and the clearing of the lumen of the vessel, while double ligature of the cleared artery excludes a recurrence of thrombosis. Suture of the artery after removal of the clot has been proposed by some, but I am of opinion that the method is rarely indicated. Badly contused tissues should never be sutured. Ligature is both sure and simple, and should always be employed in these cases.

Where gangrene is absent, the wound is invariably an old one in which a vascular lesion has passed unperceived. A day comes, however, when the vascular slough separates and formidable secondary hæmorrhage results. The treatment of secondary hæmorrhage has been described in an earlier chapter.

CHAPTER IV

WOUNDS OF THE VESSELS OF THE NECK

Wounds of the neck are usually described as superficial when the wounding agent does not penetrate beyond the deep cervical fascia. They are described as deep when the agent passes through the aponeurosis and reaches the deep layers of the neck.

Superficial wounds, involving the superficial vessels only, are not serious. Even when the anterior or the external jugular vein is involved, the hæmorrhage is quickly arrested by the slight compression of the dressing, and the venous lesions do not in any way complicate the progress of the wound.

Wounds may be *deep* and yet not involve the viscera or the great vessels. I have seen many deep cervical wounds which were not associated with serious injury; and I have frequently seen and removed projectiles lodged behind the pharynx or œsophagus, against the transverse processes of the cervical vertebræ, or in the thyroid gland, which had produced no vascular lesion. These cases are, however, exceptional, and in the majority of instances the large vessels of the neck are affected. It is proposed to consider successively wounds of the great vessels of the neck, and wounds of the vessels at

the root of the neck, together with the aneurisms occasioned by both classes of wound.

I. *WOUNDS OF THE VESSELS OF THE NECK AND ANEURISMS OF THE NECK*

A. WOUNDS OF THE VESSELS OF THE NECK

The great vessels of the neck may be injured by projectiles entering the body at such diverse points as the face, the nape, the back, and the anterior and lateral regions of the neck. The likelihood of vascular injury is, however, greatest when the orifice of entry is situated in the antero-lateral region, a little in front of or behind the sterno-mastoid.

The vascular lesions are extremely varied. They may be classified into two main groups, according to the position of the cutaneous wound and the course of the projectile, namely, wounds of the lower and middle part of the neck, and wounds of the upper part.

Wounds of the middle and lower region include all those situated between the clavicle and the upper border of the thyroid cartilage. They more particularly endanger the common carotid the internal jugular vein, the vertebral, and the inferior thyroid vessels. In some cases one vessel only, either the jugular or carotid, is injured, but more frequently both artery and vein are struck. It is by no means rare fo find that the inferior thyroid and the vertebral vessels have been injured by the same projectile. I once saw, *post-mortem*, puncture of the common carotid and section of the vertebral, both vessels having been injured by the same missile. The vascular lesion is

sometimes complicated by lesion of the pneumogastric or of the recurrent laryngeal nerve, or by lesion of a deep-seated structure, such as the pharynx, trachea, or œsophagus.

Wounds of the upper region are situated between the upper border of the thyroid cartilage and the upper portion of the parotid region. They especially endanger the internal carotid, the jugular vein, and the external carotid and its branches. Owing to their deep-seated position at the bottom of the maxillo-pharyngeal space, the internal carotid artery and the upper portion of the internal jugular vein are less exposed to injury than the external carotid, which approaches the surface at the upper part of the neck. Thus injury of the deeper vessels is usually associated with deep and extensive wounds of the parotid region; with fracture of the ramus of the mandible; or with wounds involving simultaneously the face, the bucco-pharyngeal cavity, and the upper part of the neck. Important nerve-trunks may be injured with the vessels—for instance, the pneumogastric, the glosso-pharyngeal, and the spinal accessory with the internal carotid, the hypoglossal with the external carotid, and the facial with both.

All the types of vascular wound-puncture by a minute and pointed splinter, partial or total division by a bullet or shell-fragment, perforation, extensive laceration or rupture of the vessel, are observed in connection with the vessels of the neck. Figs. 11 and 6, and fig. 2 on Plate II., show respectively perforation of the carotid bulb by a grenade-fragment, perforation of the common carotid by a bullet, and rupture of the internal carotid at its origin.

The clinical picture presented by these wounds

varies widely with the nature of the case. Where the wound is large and is associated with lesion of a great vessel, in the vast majority of cases death ensues rapidly upon the field of battle. Occasionally a man in a state of syncope is brought into the dressing station with a gaping wound in the neck, the vessel being temporarily obliterated by the formation of a clot, or hæmorrhage may recur during transit. But as a general rule, the cases which reach the surgeon are those in which the wound is perforating in character, and from which external hæmorrhage is naturally inconsiderable.

In wounds of this latter class the blood is effused into the cellular tissue surrounding the vessels and forms a diffuse hæmatoma. Occasionally, when the common carotid and internal jugular have been simultaneously struck by a projectile passing between them, there may be direct communication between the two vessels without appreciable periarterial hæmatoma. This constitutes a variety of "dry" wound. Again, in certain exceptional instances, the absence of both external hæmorrhage and hæmatoma is due to the temporary obliteration of the wound by the projectile itself, by débris of some kind, or by the collapsed and retracted edges of the vascular coats. This also constitutes a variety of "dry" wound.

Thus wounds of the vessels of the neck may be either with or without hæmatoma.

1. With a Hæmatoma.—The presence of a hæmatoma is revealed by a swelling, the position of which varies with the injured vessel. When a vessel in the lower or middle part of the neck is injured, the hæmatoma is situated at the base of the neck between

the clavicle and the thyroid cartilage. In the case of injury to vessels in the upper part, the hæmatoma is found near the angle of the mandible, in the parotid area, or the sub-mandibular region. The position of the tumour is extremely variable. An inferior hæmatoma extends towards the median line, pushing aside the larynx and trachea, and it sometimes reaches as high up as the mastoid and sub-mental regions. A superior hæmatoma, on the other hand, rarely extends down to the lower part of the neck. It tends to spread inwards, displacing the lateral wall of the pharynx and the tonsillar area, and sometimes even extends behind the pharynx and œsophagus.

The characteristics of the swelling vary according to whether the hæmatoma is venous (internal jugular), arterial, or arterio-venous in origin.

The swelling due to a *venous hæmatoma* is diffuse, soft, resistant, and without pulsation or murmur. It should be borne in mind, however, that when the common carotid is intact its pulsations are sometimes transmitted to the tumour with considerable clearness.

Arterial and arterio-venous hæmatomata, and particularly the former, are usually larger than venous hæmatomata. The swelling is harder and more tense, palpation reveals pulsation, and a characteristic murmur is observed on auscultation.

In addition to the physical signs, functional symptoms may be present. These may be due to pressure by the hæmatoma upon certain structures, or to a concomitant nervous lesion. A low hæmatoma may be associated with aphonia or hoarseness, due to lesion of the recurrent laryngeal nerve, and with extreme rapidity of the pulse, due to lesion of the vagus.

A high hæmatoma may be accompanied by dysphagia and intense dyspnœa, due in the case of peripharyngeal hæmatoma to compression of the faucial aperture.

2. Without Hæmatoma.—The mere presence of a cutaneous wound in the neighbourhood of the vessels and nerves of the neck always suggests a possible vascular lesion. The external wound may be very small, with little external hæmorrhage, which by the time the patient arrives at the dressing station is reduced to a thin trickle of blood. When the absence of external hæmorrhage and of a hæmatoma is due to the simultaneous injury of an artery and a vein leading to a communication between them, palpation will reveal a thrill, usually very slight, but unmistakable to a practised hand. When the absence of external bleeding and a hæmatoma is referable to causes other than this, there is nothing to show that there is a vascular wound. Its presence is first revealed later, by the appearance of violent secondary hæmorrhage, secondary diffuse hæmatoma, or embolism due to the lodgment of a clot in the brain.

How do these cases terminate ?

In a certain number reactionary hæmorrhage takes place whether a hæmatoma is present or not, and death may follow in a few moments. This reactionary hæmorrhage is due to the precarious nature of the hæmostasis, which is unable to withstand a sudden movement on the part of the patient, an ill-timed exploration of the wound, or even occasionally a mere rise in the blood-pressure. Repeated movements of deglutition render the neck an extraordinarily unfavourable site for the consolidation of the clot. Hence it is by no means infrequent for violent

Fig. 1.—Bullet-wound of the neck with diffuse hæmatoma.
Fig. 2.—Bifurcation of the carotid and pneumogastric nerve from patient shown in Fig. 1.

Fig. 3. —Section of the external iliac artery with lateral wound of the vein. Constrictions of the artery above the section due to rupture of the inner coats by over-stretching.
Fig. 4.—Arterial contusion. Destruction of the inner coats with preservation of the adventitia. When opened, this artery presented every degree of arterial contusion. (Latarjet's case. Val-de-Grâce Museum.)

PLATE I.

reactionary hæmorrhage, either from the external wound or from a wound of the mouth or pharynx, to occur two or three hours after the injury, at a time when all danger appears to have passed off. I again draw attention to the fact that the clot is frequently loosened and hæmorrhage precipitated by the untimely exploration of the wound. In a case of shell-wound behind the sterno-mastoid, the introduction of a finger into the wound provoked formidable hæmorrhage by the mouth and nose, which terminated fatally within a few seconds (Maisonnet).

In a second group of cases the patient escapes reactionary hæmorrhage as he has already escaped primary hæmorrhage. The progress of the wound then depends solely upon the question of its infection or non-infection.

A wound produced by a missile which has traversed the nose, mouth, or pharynx is infected from the start. The first signs of a circumscribed or diffuse cellulitis of the neck, gaseous or non-gaseous, make their appearance the day after the injury has been received. Swelling appears or becomes increased; œdema occurs over the whole of the front of the neck and spreads to the subclavian region; and a brownish, sometimes fœtid, discharge escapes from the wound. The temperature rises, and all the general symptoms of severe infection make their appearance. The almost inevitable consequence of infection of the hæmatoma is secondary hæmorrhage.

Secondary hæmorrhage is chiefly seen in association with badly infected wounds of the upper part of the neck, the parotid region, and the sub-mandibular triangle, which are often complicated by wounds of the mouth and pharynx and by fracture of the jaw, all of

which are eminently septic, and predispose to a rapid and destructive gangrenous infection. In other words, wounds of the suprahyoid part of the internal jugular vein, of the internal carotid, or of the external carotid and its facial, lingual, and internal maxillary branches are extremely liable to secondary hæmorrhage. Secondary hæmorrhage may be direct, the blood escaping from the skin wound, but when the hæmatoma is in communication with the upper digestive tract, the nose or the mouth, the blood may be extravasated into these cavities. Sometimes it invades the respiratory passages, causing death by suffocation. When a nerve injury has caused laryngotracheal anæsthesia, and thus abolishes the reflexes of warning and defence, the trachea and bronchi may become filled with blood. Makins has published a case in which death followed secondary hæmorrhage from a wound of the common carotid involving the pharynx. The hæmorrhage took place into the larynx and trachea without provoking the slightest symptom. The autopsy showed that the pneumogastric had been severed.

If the wounding agent is a bullet or minute shell-fragment, if the skin wound is punctiform, and the digestive passages are not involved, the wound in the vessel may be regarded as primarily aseptic. These wounds tend towards arterial or arterio-venous aneurism, both of which conditions are prone to grave complications, such as sudden and rapid increase in size, infection of the sac, and cerebral embolism.

It is evident then that those patients with a wound of the great vessels of the neck, who escape death from primary hæmorrhage on the battlefield, are liable to either reactionary or secondary hæmorrhage. In

the case of shell-wounds these complications are almost invariable, but they are far from exceptional in connection with bullet-wounds.

Indications for Treatment.—The object of treatment in large, lacerated wounds is to arrest primary or reactionary hæmorrhage; in infected punctured wounds, the object is to prevent secondary hæmorrhage. The methods of achieving these objects are as follows :—

As a general rule, extensive wounds of the neck are not amenable to surgical treatment. It occasionally happens, however, that either at the dressing station or during transport a wound of the neck temporarily closed by clots gives rise to a sudden reactionary hæmorrhage of most alarming profuseness. What should be done by the orderly who happens to be at hand when the bleeding occurs, or by the medical officer in charge of the first field-dressing station where surgical conveniences are usually so restricted ? The common carotid should be immediately compressed, either against the spinal column in front of the sterno-mastoid, or by pinching it in the manner shown in fig. 44. If this does not stop the hæmorrhage, direct pressure should be exercised by a finger thrust into the wound. Digital pressure must, however, be regarded as a dangerous makeshift, to be used in any case for a

FIG. 44.—Compression of the carotid. (After Farabeuf.)

few moments only until more efficient measures can be devised. Personally, I infinitely prefer to close the skin wound with one or more pair of clamp-forceps. It is true that this gives rise to a hæmatoma which must be dealt with immediately the patient reaches the field ambulance, but it prevents him from dying of hæmorrhage on the way there. I have already referred to a case in which primary hæmorrhage from a large wound with section of the common carotid was arrested by closing the skin wound with a Kocher's forceps. The patient arrived at the dressing station with an large hæmatoma of the neck, but at any rate he arrived there alive. Closure of the skin wound is a simple, easy, and efficient way of arresting the formidable hæmorrhage which occurs in extensive wounds of the neck.

AT THE FIELD AMBULANCE the surgeon may have to deal with either a lacerated and bleeding shell-wound, or with a bullet-wound the punctiform orifices of which are already almost closed.

In the case of the shell-wound, there is no doubt as to the method of procedure. Whether a hæmatoma is present or not, we have to do with an infected wound which must inevitably become the seat of septic complications of the most serious kind, with all the risks of grave secondary hæmorrhage. Immediate operation is imperative. Free exposure of the wound is the only way to prevent infection, and direct hæmostasis is the only preventive of secondary hæmorrhage.

Where the wound has been made by a bullet or minute shell-fragment the question is not so simple. Here, as elsewhere, immediate operation is indubitably called for in the case of a large hæmatoma.

which is increasing steadily and rapidly, compressing the air-passages, distending the skin, and threatening to burst externally. Such cases as these, however, are exceptional; as a general rule, the hæmatoma is either small or medium in size, or it may be absent altogether.

Take the case of a medium-sized hæmatoma, due to a bullet-wound in the neck. One might say that the obvious course is to wait until the hæmatoma becomes encapsuled and diminishes. After all, there is no hurry to operate. A venous hæmatoma due to a wound of the internal jugular vein will get smaller and gradually become absorbed, and if this is so, spontaneous recovery will be rapid and complete. An arterial hæmatoma will tend also to become encapsuled, and to end as a smaller and more circumscribed aneurism, during the formation of which the wound will become healthy and the collateral circulation will be established. Should it be necessary to operate upon this aneurism, late operation will be far less serious than a primary one, for it is well known that the mortality in primary ligature of the common carotid is 50 per cent., while in aneurism of the carotid it is only 15 per cent.

This train of reasoning appears even more plausible when it is applied to a circumscribed arterio-venous aneurism. It seems so much better to postpone operation until after the hæmatoma has contracted and the arterio-venous circulation has settled down; in other words, to await the formation of an arterio-venous aneurism. Again, in simple communication between an artery and a vein why not postpone operation until after cicatrisation of the wounds, an operation which perhaps time and rest may render unnecessary?

Generally speaking, I do not agree with this line of argument. In the first place, primary operation is the sole means of guarding against possible complications, such as infection of the hæmatoma, sudden increase in its size, and cerebral embolism. But even assuming that in association with bullet-wounds these secondary complications are sufficiently rare to be disregarded, I believe early operation to be easier and, in the majority of cases, less dangerous than one at a later date.

The contraction and consolidation of the hæmatoma is accompanied by contraction of the neighbouring cellular tissue; by compression, sclerosis, and matting together of the adjacent structures; and by adhesion of the jugular vein, the pneumogastric and recurrent laryngeal nerves, etc., to the peripheral layers of the sac. The more complete the matting, the more difficult and dangerous will be the dissection of the sac. It may even happen that, whereas incision of the primary hæmatoma would have been a simple matter, extirpation of the subsequently formed aneurismal sac is impossible. The transformation of an arterio-venous hæmatoma into an arterio-venous aneurism is accompanied not only by the intimate fusion of the sac with all the neighbouring structures, but by dilatation and occasionally thinning of both ends of the jugular to such an extent as greatly to increase the difficulties of operation. Even a simple communication between artery and vein becomes daily more difficult to operate upon. The two vessels become gradually more firmly adherent, and the vein is distended to excess and becomes matted to the adjacent tissues. The aneurism will have thus become impossible to extirpate, although it

originated in two small arterial and venous wounds which might so easily have been repaired. A case of Rouvillois is very instructive in this connection. He waited six weeks before operating upon an arterio-venous hæmatoma which, in the first instance, demanded no more than ligature of the common carotic and of the internal jugular vein. He found an intimate fusion of the vessels which were firmly matted to the surrounding structures. He was obliged to ligature the common carotid, the internal carotid, the external carotid, and the jugular vein, and even then he was compelled to abandon the attempt to extirpate the sac.

To those who advance the gradual establishment of the collateral circulation as a plea in favour of the later operation my reply is as follows: The lesion of the carotid has from the first resulted in the formation of either a peri-arterial hæmatoma, which compresses the vessel and interrupts the circulation; or an arterio-venous hæmatoma, which conveys the blood intended for the periphery into the central end of the jugular vein; or it has not produced a hæmatoma owing to the obliteration of the vessel by the projectile, a portion of débris, or a clot. In any case, the circulation at the level of the carotid wound is arrested in exactly the same way as if the vessel had been ligatured, and ligature merely converts the temporary arrest of hæmorrhage into a permanent one. Thus if no signs of cerebral derangement are present when the patient first comes under observation, it is highly probable that ligature of the vessel will not produce them. Moreover, early operation is compatible with the obliteration of a very limited vascular segment, whereas the later operation

necessitates the obliteration of a very much larger one —for instance, ligature of the internal and external carotids in addition to ligature of the main trunk. Extensive obliteration such as this greatly increases the risk of cerebral complications. For these reasons I believe that in cases of wounds of vessels of the neck, even when produced by projectiles of small calibre, immediate surgical intervention is indicated.

Having disposed of the general indications, we now arrive at the choice of method.

1. WOUNDS OF THE MIDDLE AND LOWER PARTS OF THE NECK.—A wound in the middle or lower part of the neck with subhyoid hæmatoma suggests a wound of the common carotid, the internal jugular vein, the vertebral, or the inferior thyroid vessels. Desirable as it undoubtedly is to ascertain before operation which vessel is wounded, such a preliminary diagnosis is rarely possible. A subhyoid hæmatoma which is not tense, and has neither pulsation nor murmur, suggests a venous hæmatoma. A hæmatoma with pulsation and murmur suggests an arterial hæmatoma, either carotid or vertebral, but it is practically impossible to distinguish which. The obvious course is to practise digital compression of the common carotid against the carotid tubercle, but this manipulation reveals nothing, and, generally speaking, operation is the sole means of diagnosis. It must be admitted, however, that nine times out of ten the source of the trouble is in the carotid.

The first operative step is to provide for temporary hæmostasis by securing the common carotid low down in the neck.

Ligature of the common carotid low down in the neck.—A longitudinal incision is made along the

anterior border of the sterno-mastoid muscle, beginning 3 inches above the clavicle and terminating at the level of that bone. Beneath the skin and platysma is the anterior border of the muscle in its sheath of deep cervical fascia. The fascia is incised either along the anterior border of the muscle or, very lightly, outside it, and the muscle is retracted outwards, and the larynx and trachea inwards. The carotid is then exposed by incision of the deeper layer of the fascia enclosing the sterno-mastoid. To isolate the vessel and pull it up on a temporary ligature is a simple matter.

Exposure and incision of the hæmatoma.—When all immediate risk of grave hæmorrhage has thus been obviated, attention is turned to the hæmatoma. As a general rule, the incision already made for the ligature is insufficient, even if it be prolonged upwards. The retracted edges of the wound and the muscles form a deep trench, at the bottom of which it may be possible to ligature a normal vessel, but which does not give enough room to expose and properly deal with a wounded one. Free exposure is essential, and the best way to get this is to raise a skin flap and temporarily divide the sterno-mastoid. A perpendicular incision should be made from the centre of the longitudinal one, running upwards towards the chin (Morestin). Or two incisions, starting from the same point, should be made, one upwards and forwards towards the chin, the other downwards and backwards towards the supraclavicular fossa. In the first case the incision will resemble a triradiate star (Morestin), in the second it will be crucial (fig. 45). The entire lateral region of the neck can thus be easily exposed, and trans-

verse section of the sterno-mastoid will expose the vessels freely (fig. 46).

Before opening the hæmatoma an attempt should be made to determine which vessel is wounded. If

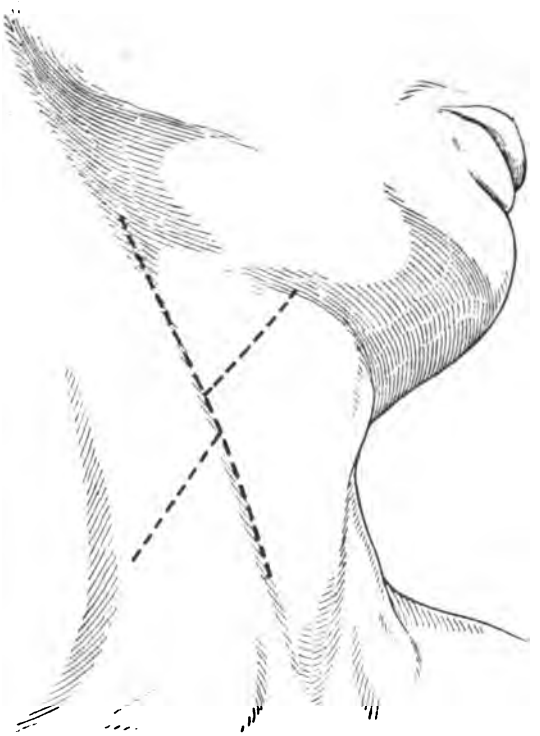

FIG. 45.—Crucial incision to expose the vessels of the neck.

a pulsating hæmatoma ceases to beat on temporary occlusion of the carotid, it is certain that the hæmatoma is of carotid origin. If it continues to pulsate, the lesion is probably in the vertebral. It is best to make certain by digital compression at the bottom of the wound exactly over the foramen in the transverse process of the sixth cervical vertebra. If the pulsa-

tions cease, lesion of the vertebral is certain. It occasionally happens that transmitted pulsations are mistaken for true pulsations, the hæmatoma being of purely venous origin, due to lesion of the jugular vein.

FIG. 46.—Exposure of the vessels of the neck.

The true state of the case is not perceived until after incision of the hæmatoma.

The second stage of operation consists in the free incision of the hæmatoma. To remove the blood and clots is the work of a few seconds, and the wound is well sponged out, when the wound in the vessel is usually easy of discovery.

(*a*) *Wound of the internal jugular vein.*—The vessel is dissected out and ligatured above and below

the wound; if necessary, the intervening portion is divided. It is sometimes necessary to ligature the vein at the junction of the great thyro-facio-lingual branches. In such a case the latter should also be tied, either *en bloc* or each branch separately.

Ligature of the internal jugular is a simple, certain, and safe operation. I use the word "safe" advisedly, for the cerebral complications which were formerly attributed to this ligature are quite exceptional unless infection is present. The case described by L. Bazy, in which a fatal hemiplegia followed ligature of this vein, is striking in its rarity. Modern surgery of the neck and aural cavities has shown that the internal jugular may be divided, ligatured, and resected without provoking the slightest complication. These experiences are confirmed by the results of war-surgery. I have twice tied this vein for primary or secondary hæmorrhage without the least untoward symptom. The simplicity of ligature does away with any necessity for lateral or circular suture of the vein. These methods have been attempted two or three times since the beginning of the war, but there is no certainty that the permeability of the vessel was preserved in any case. To suture the internal jugular is uselessly to prolong operation, and the method should be rejected in favour of ligature.

(*b*) *Wound of the common carotid.*—Wounds of this artery may be either sutured or tied.

Ligature above and below the wound is both simple and easy. If the common carotid artery and the internal jugular vein are injured, both artery and vein should be tied. If, as in a case described by Guibal, the venous wound is situated at the junction

of the jugular with the subclavian vein, it may even be necessary to tie the innominate vein at the root of the neck. Cases such as these, however, properly come under the heading of wounds at the root of the neck, and these will be dealt with separately. Under normal conditions, when these ligatures have been tied, the temporary ligature is removed from the common carotid, and permanent hæmostasis is completed where necessary by supplementary ligatures.

What are the results of this operation?

It has long been recognised that ligature of the common carotid may provoke *complications*, both *immediate* and *remote*.

The immediate complications are due to ischæmic necrosis of the cerebral cells and of the ocular nerve cells. They are manifested by *hemiplegia* and *amblyopia* or *amaurosis*, and are the outcome of extreme anæmia of the brain. It is quite possible for ligature of the common carotid to result in sudden arrest of the blood-supply of the corresponding hemisphere of the brain. Reliable clinical observations have shown that such accidents do take place immediately the ligature has been tied. They are, however, extremely rare, and there are grounds for believing with Guinard and others that these complications do not arise where the normal anastomotic communications are intact. It is certain that the normal anastomoses between the right and left carotid regions are very free. After section of the facial, lingual, or external carotid arteries it is a common event for the blood to be projected as forcibly from the peripheral as from the central end of the divided vessel. Under such circumstances the reversal of the blood-stream by arrest of the circulation through the right external carotid

may be instantaneous, and the re-establishment of the circulation to the brain by way of the internal carotid may, in consequence, be immediate. Thus after ligature of the common carotid the blood will rapidly and easily resume its course, provided that the anastomotic branches of the external carotids are normal. Sudden complications are favoured by arterial abnormalities, atheroma, previous or simultaneous ligature of the arterial branches of the face —by all the factors, in fact, which are liable to impede the circulation in the collateral vessels. In young subjects free from atheroma these complications are undoubtedly exceptional.

Simultaneous ligature of the internal jugular does not increase the risk of cerebral complications; it appears indeed to diminish them. Several authors state that immediate cerebral complications are relieved by measures which tend to drive blood to the brain (moderate elastic pressure round the base of the neck, nitrite of amyl inhalations, etc.). More efficacious still is ligature of the internal jugular vein.

Remote complications are observed some hours after ligature, generally from the end of the first day to the end of the third (de Fourmestraux). They are the outcome of arterial thrombosis of infective origin, which starts at the site of ligature and spreads upwards, by way of the internal carotid, to the sylvian and ophthalmic vessels.

Only very few cases of wounds of the common carotid operated upon in field ambulances and front-line hospitals have been published. I operated upon one very interesting case in which recovery was complete and uneventful. Lerat operated upon a large

hæmatoma in the lower and middle region of the neck. He ligatured the common carotid, the superior thyroid, and the internal jugular. The patient showed some torpor and somnolence, but recovered without trouble. In a similar case Moiroud ligatured the common carotid and internal jugular without complications. On the other hand, a patient of Maisonnet's died two hours after ligature of the common carotid, superior thyroid arteries, the internal jugular, and thyro-facio-lingual veins. Makins reports two cases of ligature of the common carotid for diffuse hæmatoma, with one recovery and one hemiplegia. I am well aware that so restricted a number of observations cannot be regarded as furnishing conclusive evidence as to general results. Nevertheless, I think that there is justification for the belief that in the case of a young and vigorous subject, where hæmorrhage has not been excessive, ligature of the common carotid is rarely accompanied by complications.

Suture of the common carotid may be lateral or circular, with or without venous transplantation. After free exposure of the vascular wound, lateral suture is simple and easy, provided always that the wound is not larger than a lentil. Circular suture is a longer and more delicate operation. Suture offers the great advantage of securing arrest of hæmorrhage while excluding cerebral complications. The method is said, however, to carry with it the danger of cerebral embolism. The suture site is supposed to form a centre of thrombosis from which clots are conveyed to the brain. This objection is purely theoretical. Aseptic suture is no more subject to thrombosis than ligature. Out of six cases of lateral suture of the

common carotid collected by Monod and Vanverts in 1910, not one was accompanied by cerebral complications. The sole objection to suture of the carotid is its difficulty. In order to render lateral suture safe and efficacious the edges of the vascular wound must be carefully cut away until all trace of endothelial laceration has been removed. This frequently results in a gap which exceeds the limits of possible lateral suture, necessitating circular suture, which is not only more difficult but is a longer and more hazardous procedure. This fact explains the infrequency of vascular suture; indeed, I cannot cite a single instance of its employment in recent injury. I attempted lateral suture in one case of perforation of the carotid bulb by a shell-fragment, but was compelled to abandon the operation owing to the friability of the edges of the wound.

The choice of method, then, lies between ligature of the vessel, a simple, easy, and efficient method rarely attended by complications, and vascular suture, a method which, though undoubtedly easy in its simplest form, is more often tedious and delicate. The inferences are that, where lateral suture appears simple and easy of execution, it should be performed; in all other cases, ligature is indicated.

2. WOUNDS IN THE UPPER PART OF THE NECK.—A wound in the upper part of the neck or its immediate neighbourhood, with a hæmatoma about the angle of the mandible or in the sub-maxillary region, suggests a lesion of the internal jugular vein, the bifurcation of the carotid, the internal or the external carotid or its branches. Here also it would be expedient to determine which vessel is wounded before operating, but this is rarely possible. A deep-seated

swelling, invading the isthmus of the fauces or the wall of the pharynx, suggests a lesion of the internal carotid; a superficial hæmatoma, associated with absence of the temporal pulse, suggests one of the external carotid. But these suggestions are very vague, and it is only by operation that the precise site of the vascular injury can be determined.

Here again the first operative step consists in temporary hæmostasis by provisional ligature of the common carotid at the root of the neck.

Exposure of the hæmatoma constitutes the second step, and here also a simple longitudinal incision is usually insufficient to expose the branches of the carotid.

I would remind my readers that the classic method of exposing the internal and external carotids is by an incision along the anterior border of the sterno-mastoid, starting from the angle of the jaw and terminating at the level of the superior border of the thyroid cartilage. The platysma is divided, and beneath it the deep cervical fascia along the anterior border of the sterno-mastoid. The muscle is retracted outwards, and the greater cornu of the hyoid bone is located with the finger at the bottom of the wound. The deep layer of the deep cervical fascia immediately above the cornu is divided. Under this layer lie the thyro-facio-lingual veins below, the hypoglossal nerve above, and between the two a large arterial trunk, the external carotid. The artery is recognised by its collateral branches.

This simple longitudinal incision is insufficient for the exposure of a large hæmatoma in the upper part of the neck. It should therefore be supplemented either by a transverse incision across the sterno-

mastoid, producing a crucial incision, or by Morestin's triradiate incision. By either method the whole of the region in question is freely exposed. The next step is to open the hæmatoma, and, after this has been well cleared out, the vascular wound is readily seen.

(*a*) *Wound of the internal jugular vein*.—I should not return to this subject were it not that the extreme upper part of the neck possesses certain anatomical peculiarities which render these jugular wounds exceedingly difficult to treat. Up to the level of the lower border of the parotid gland the jugular vein is easy of access, and may be seen at the bottom of the wound. To catch the two ends and tie them is the simplest matter. But higher up, beneath the base of the skull and near the jugular bulb, a lesion of this vessel may be extremely difficult to manage. Even when the jaw is pulled well forwards and the parotid is retracted backwards and outwards it is not possible to obtain a clear view of the bottom of the wound whence the hæmorrhage proceeds. By catching the bleeding point at hazard with the forceps one runs the risk of pinching the pneumogastric, glossopharyngeal, or spinal accessory nerves without arresting the hæmorrhage. The hæmorrhage being of venous origin a pad may be applied in the mandibulopharyngeal space, but this is merely a measure of expediency. In one case of the kind I followed the method recommended by Lannois and Patel, which consists in arresting hæmorrhage from the internal jugular by compression or ligature of the corresponding lateral sinus. The sinus is exposed by either the mastoid or post-mastoid route.

The mastoid operation, of which I have personal experience, is carried out as follows :—

The post-auricular tissues are incised as in the operation for opening the mastoid. The mastoid antrum is opened in the usual manner. By enlarging the opening backwards with the mallet and chisel and removing the remaining mastoid cells with the curette the sinus is reached. It is exposed to the extent of one square centimetre, and is then either tied or compressed against the bony groove by means of a plug of aseptic gauze in such a way as to arrest the circulation. The skin is then sutured over the plug, the ends of which are allowed to emerge from the lower end of the wound. At the end of a week the plug is removed. An insignificant cicatrix is the sole trace of an operation which should not take more than a quarter of an hour.

Experience shows that this operation is quite free from danger; complications are as rare as after ligature of the jugular vein. It has the advantage, moreover, of being absolutely effectual. After plugging the lateral sinus, the jugular bulb and the subjacent portion of the jugular vein become flaccid and flattened and cease to bleed. The arrest of hæmorrhage is immediate. I consider ligature or obliteration of the lateral sinus by Lannois and Patel's method a most valuable operation in wounds of the upper part of the neck with lesion of the jugular bulb or the portion of the vein immediately below it.

(*b*) ***Wound of the internal or external carotids or their branches.***—The wound may be single, but is generally multiple. Where one vessel only is injured it may be either the internal or external carotid, or it may be a branch of the external carotid, the lingual, facial, or internal maxillary. I have seen very large hæmatomata in the hyoid region, with enormous elevation

of the floor of the mouth, compression of the base of the tongue, and threatened asphyxia due to a wound of the lingual. In one case immediate tracheotomy was necessary. As a general rule, however, the carotid trunks themselves are injured.

Having exposed the arterial wound, what is the next step? It goes without saying that if a branch of the carotid is injured it should be tied. Nothing could be easier or more free from danger. The conditions are not the same, however, when the carotid trunks are injured.

If the wound is in the carotid bulb or in one of the two main branches, but is situated so close to the common trunk that it is impossible to place a ligature upon the vessel between its origin and the wound, it will be necessary simultaneously to tie the common carotid below the wound and the external and internal carotids above. What is the result of the triple ligature?

In view of what has been said in a previous paragraph concerning the re-establishment of the cerebral circulation by way of the anastomoses of the external carotid, triple ligature of the carotid bifurcation should considerably endanger this re-establishment. Indeed, might not the resulting complications prove fatal? Experience shows, however, that this is not the case. It is true that triple ligature has not been employed in recent injury. I was unwilling to attempt it in a case of perforation of the carotid bulb by a shell-fragment, which came into my hands less than an hour after injury. I at first attempted suture, but was forced to abandon it owing to the damaged condition of the edges of the wound. I then performed anterior and posterior lateral ligature, after having to

divide the superior thyroid, which prevented me from rotating the vessel. Recovery followed without incident. The temporal pulsation could be distinctly felt after operation and until after recovery. Out of seventeen cases of carotid hæmatoma collected by Monod and Vanverts in 1910, three were wounds of the bifurcation of the carotid, and necessitated triple ligature. In two of the three cases cerebral complication ensued, but eventual recovery took place in all three. Since the war, Duval in one case ligatured the common and the external carotid; no complications ensued. Hallopeau ligatured the external carotid, the internal carotid, and the internal maxillary without provoking complications. Finally, both Quénu and Rouvillois have performed triple ligature with recovery in certain old injuries resulting in arterio-venous aneurism. Quénu's patient presented a slight hemiplegia, which disappeared in the course of half an hour. All these facts go to show that cerebral complications do not necessarily follow ligature of the bifurcation of the carotid. Such complications are, however, none the less to be dreaded, and the possibility of their arising should never be lost sight of. My own view is that in such cases it is advisable to practise lateral suture where possible and lateral ligature where necessary, resorting to triple ligature only as a last resource.

What is the best method of dealing with cases where the wound is situated in the external or internal carotid, at such a distance from the bulb that double ligature is possible? Double ligature of the external carotid is simple and safe, and should always be performed. Ligature of the internal carotid is, on the contrary, a very serious operation. The

appearance or absence of cerebral symptoms depends solely upon the poverty or the profusion of the cerebral anastomotic communications, and it is not possible to ascertain their condition beforehand. For this reason I urge, even more strongly than in the case of the common carotid, that lateral suture should be attempted wherever possible before recourse is had to double ligature, the prognosis of which is so uncertain.

Summary.—Wounds of the neck, whether lacerated or punctured, should be treated by free exposure of the site, incision of the hæmatoma after temporary control of the common carotid, and direct arrest of hæmorrhage in the wound. Wherever possible, arrest of hæmorrhage should be obtained by arterial suture. This applies particularly to wounds of the carotid bulb and of the internal carotid. In all other cases permanent double ligature should be performed.

B. ANEURISMS OF THE NECK

1. Arterial Aneurism.—Arterial aneurism following wounds of the vessels of the neck due to projectiles of war is extremely rare. The immediate gravity of these wounds is such, that in the absence of early surgical treatment the vast majority of cases succumb, and very few arrive at the stage of true traumatic aneurism. Within the last two years, however, a few cases have come under observation.

The aneurism may be situated in any region of the neck.

An aneurism situated in the middle and inferior region is connected with the common carotid. The

tumour may be either immediately above the clavicle, or as high up as the superior portion of the larynx. As a general rule it is inconsiderable in size. On two occasions during the year 1915 Walther showed a patient before the Société de Chirurgie with an aneurism of the common carotid following a shell-wound. The tumour was in process of diminution, and, when it first came under observation, was not larger than a hazel-nut. In appearance the aneurism is an ovoid tumour, with its long diameter parallel with the direction of the vessel. It is situated in front of the sterno-mastoid, which it pushes backwards and outwards. The tumour is immobile both transversely and longitudinally. It is soft and resistant, and both pulsation and expansile movements are very marked. The characteristic murmur is heard on auscultation.

Aneurism of the upper part of the neck is in connection with either the internal or the external carotid. The tumour is situated in the upper part of the sterno-mastoid area below the mastoid process, occupying the parotid and submaxillary regions and about the angle of the mandible. It may extend towards the pharyngeal wall along the prolongation of the parotid gland, especially if it originates in the internal carotid.

The course of these tumours is generally progressive and rather rapid. Spontaneous recovery is exceptional. As a general rule the initial slight functional troubles increase progressively. These are due to disturbance of the cerebral circulation; they are manifested by vertigo, insomnia, throbbing pains over the whole of the side of the head corresponding to the site of injury, somnolence, etc. Pressure upon

the nerves in the neighbourhood of the tumour shows itself by pains in the neck and arm, due to compression of the cervical and brachial plexuses; ocular disturbance due to compression of the sympathetic; hoarseness and dyspnœa due to compression of the recurrent, pneumogastric, and phrenic nerves; and dysphagia and dyspnœa due to compression of the deep structures of the neck. The intensity of these derangements alone may endanger life; as a general rule, however, the catastrophe is precipitated by a sudden increase in the size of the tumour, its inflammation, or its rupture either externally or into the digestive or air passages.

For these reasons arterial aneurisms of the neck should be operated upon unless they are very small and unaccompanied by symptoms.

In a previous chapter it was laid down that the treatment of choice for arterial aneurism in general is extirpation. This applies equally to arterial aneurism of the neck.

The first step in the operation is exposure of the tumour. Here, as in cases of recent wounds, simple longitudinal incision is replaced by either a triradiate or a crucial incision with section of the sterno-mastoid (see p. 167). When the tumour has thus been exposed, the next step is to ascertain which vessel has been wounded. Aneurism of the common carotid at the root of the neck is recognisable at a glance. Those situated higher up, especially if the sac extends rather low, are less easy of diagnosis. It is only by exposing the common carotid and its bifurcation, and by stopping the pulsation of the aneurism by temporary compression of the arterial trunks in turn, that a diagnosis can be established.

When this point has been satisfactorily ascertained the afferent and efferent trunks are temporarily secured as close as possible to the two poles of the sac, which is then carefully dissected out; the jugular, the vagus, the hypoglossal, and other nerves and vessels more or less adherent to its wall are carefully freed; by this means the tumour is gradually isolated until it is only attached to the wounded vessel by a narrow pedicle, which is then severed and the aneurism removed. All that now remains to be done is to deal with the wound in the vessel left by excision of the tumour. In some cases there is only a slight lateral loss of substance; more frequently, however, there is a circular loss of half an inch or more.

Here again the choice lies between ligature and suture, as far as the common and internal carotids are concerned. Monod and Vanverts have shown that out of eleven cases of extirpation of aneurism of the common carotid with ligature of both ends of the vessel, collected by them in 1910, in one case only did death occur thirty-one days after operation as the result of pneumonia. Two cases of extirpation of aneurism of the internal carotid were both successful. It is evident then that ligature is not much to be feared, and this is not remarkable in view of the ample time allowed for establishment of the collateral circulation.

That complications may, however, occur is shown by a case of Morestin's, published since the war, in which extirpation of an aneurism of the internal carotid was followed some hours after operation by cerebral complications ending fatally. Notwithstanding, suture under such conditions is rarely indicated, and indeed I do not know of an instance

in which it has been employed. In arterio-venous aneurism the case is different, as will be shown later.

Extirpation, which is not in reality a very serious operation, is unfortunately not always practicable. Removal of the tumour is sometimes obviously impossible from the start, and if the operation is attempted it may be impossible to terminate it. In such cases recourse is had either to proximal ligature, or to combined proximal and distal ligature. Proximal ligature is a very simple operation, and, according to figures given by Monod and Vanverts, it has a definite value in the treatment of carotid aneurism. These authors collected seven cases of proximal ligature of the common carotid, six of which were successful and one doubtful.

2. Arterio-venous Aneurism.—Arterio-venous aneurism of the neck is more frequent than the arterial form. In the majority of cases it is associated with either the middle or inferior portion of the common carotid.

It frequently assumes the form of aneurismal varix. Out of fourteen wounds of the carotid vessels observed by Makins, in seven there was aneurismal varix. In the last two years twenty cases have been operated on and described in France alone. When the lesion assumes the form of varicose aneurism the sac is comparatively small. In a case of Soubbotitch's, however, it attained the dimensions of a hen's egg. Fig. 47 shows an arterio-venous aneurism of the internal carotid the size of a mandarin orange. Like arterial aneurism, arterio-venous aneurism appears as a small, soft, immobile, ovoid tumour, over which there is the characteristic thrill and a continuous murmur which becomes stronger at the

systole. A feature peculiar to arterio-venous aneurism of the neck is the consciousness by the patient of a perpetual humming or vibration in the head. This symptom may become sufficiently pronounced to cause intense suffering.

The course of these tumours is usually very slow. Spontaneous recovery is exceptional. Nevertheless both Pozzi and Routier last year showed patients before the Société de Chirurgie who had presented a marked aneurismal thrill some months previously, which had completely disappeared under the influence of rest. As a general rule, the pain and vertigo due to circulatory disturbance of the brain, as well as the cardiac troubles, become progressively more intense, necessitating surgical intervention.

FIG. 47.—Arterio-venous aneurism of the internal carotid artery and the internal jugular vein at the base of the skull. (Latarjet's case. Val-de-Grâce Museum.)

It has already been laid down that the aim of all treatment of arterio-venous aneurism is the permanent separation of the two currents of blood which have become pathologically intermixed. The ideal operation consists in exposing the communication, separating the two vessels by careful dissection, and repairing each of them.

During the last two years this operation has been

performed a certain number of times on the vessels of the neck.

The first step consists in the free exposure of the lesion. Here, as in the cases already dealt with, a flap should be raised and the sterno-mastoid divided. When the tumour has been well exposed, an attempt should be made to identify the anastomosed vessels. Arrest of pulsation on compression of the common carotid or one of its branches constitutes a valuable diagnostic sign. An artery-clamp is placed on the afferent artery as near to the communication as possible; in the case of a varicose aneurism, as close as possible to the inferior pole of the tumour. Where practicable, the efferent artery should be compressed in a similar manner quite close to the superior pole of the aneurism.

In the case of simple aneurismal varix the two vessels are gradually separated from one another and from the surrounding tissues. In the course of this manipulation the surgeon comes upon a little fibrous channel uniting the jugular and the carotid. If this channel is sufficiently long it may be tied; a better method is to divide it between two ligatures. If it is short, it is merely divided. The surgeon has now to deal with a lateral arterial and a lateral venous wound. The artery should be repaired by a fine continuous suture. Suture of the vein is inexpedient; the best method of treating the venous lesion is by double ligature.

In the case of a varicose aneurism the sac is dissected out and detached. Its removal involves complete section of both artery and vein, with or without loss of substance. The venous wound is treated by double ligature. When the loss of substance is very

small, the arterial wound should be repaired by circular suture; when it is more extensive, a venous segment cut from the jugular should be grafted in between the cut ends of the artery.

Reparative operations of this nature have during the last two years been performed with some frequency. In a case of aneurismal varix Soubbotitch isolated the common carotid and the jugular, both of which presented an orifice the size of a haricot bean. He sutured both wounds, and his patient recovered. In a case of jugulo-carotid varicose aneurism, Hotz extirpated a large portion of the tumour when he discovered that both artery and vein had been divided. He tied the two ends of the jugular and united the artery by circular suture, in spite of a loss of substance of half an inch. The circular suture held perfectly. On the ninth day slight secondary hæmorrhage occurred, and the wound was reopened. The carotid suture held well, and the pulsation of the artery was normal. Nevertheless the artery was ligatured. In another case, after extirpation of a jugulo-carotid arterio-venous aneurism, Hotz found that 2 inches of the common carotid were missing at the bifurcation. He tied the external carotid and implanted a venous segment 3 inches in length, obtained from the internal saphena vein, between the internal and the common carotid. The patient recovered.

These results cannot be regarded otherwise than as extremely encouraging. Unfortunately, however, the methods by which they are obtained are not invariably practicable. It is not certain, moreover, that even where practicable these methods are always indicated. Much depends upon the site of the

aneurism. Where the arterio-venous connection or aneurismal sac situated on the common carotid is sufficiently far below the bifurcation to admit of the main trunk being tied below it, experience has shown that ligature is attended by very slight risk. In 1915 Quénu collected ten cases of arterio-venous aneurism of the neck, in which the common carotid was resected and tied under these conditions without complications. Since the war the operation has been performed without complications by Duval, Soubbotitch, Guibal, and no doubt by others. Even in cases where the ligature is close to the bifurcation of the carotid the complications are not fatal. It is probable that the fall in the blood-pressure at the peripheral end of the carotids, due to derivation of arterial blood by the vein, results in re-establishment of the cerebial circulation from the opposite side. However this may be, out of five cases of ligature of the bifurcation of the carotid collected by Quénu, in three only were there transient complications. Since then Bérard, Duval, and Rouvillois have all tied the three branches of the carotid fork without complications.

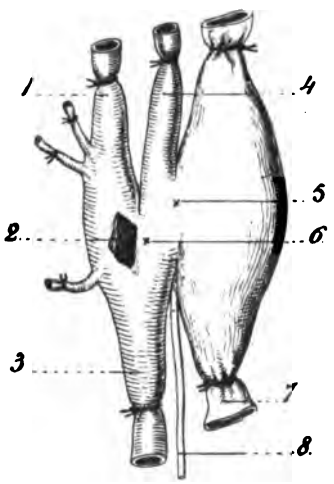

FIG. 48.—Jugulo-carotid arterio-venous aneurism. (Unpublished case of Bérard.)

1. External carotid. 2. Portion of shell extracted from the external carotid, which had also wounded the internal carotid. 3. Common carotid. 4. Internal carotid. 5 and 6. Points at which the arterio-venous communication was effected. 7. Dilated internal jugular vein. 8. Pneumogastric nerve.

It is evident, then, that when suture of an arterial aneurism is in the least difficult, the vascular segment may be extirpated and the four trunks tied. Further, that an aneurismal varix may also be extirpated and the affected trunks tied without provoking serious cerebral complications.

It must however be borne in mind that, in a certain number of cases, extirpation of the aneurismal sac is discovered, either before or during operation, to be impracticable. In such a case partial extirpation and quadruple ligature should be performed—that is to say, ligature of both artery and vein above and below the anastomosis. Where it is necessary to tie the carotids above the bifurcation, or simultaneously to ligature the jugular and subclavian veins below the junction of the jugular with the subclavian vein, quintuple ligature is indicated. When the branches of the external carotid or of the internal jugular participate in the constitution of the sac, multiple ligature is indicated. In one case of this kind operated upon by Bérard, ligature of the common, internal, and external carotids was insufficient to dry the sac; blood was returned to it by the thyroid, facial, and lingual branches, and it was necessary to tie these in order to arrest the hæmorrhage (fig. 48).

II. WOUNDS AND ANEURISMS OF THE VESSELS AT THE ROOT OF THE NECK

A. WOUNDS OF THE VESSELS AT THE ROOT OF THE NECK

The innominate, the subclavian, and the origin of the carotid arteries, together with the corresponding

veins, may be injured by bullets or shell-fragments, which either graze the upper border of the clavicle and penetrate the neck horizontally from back to front, traversing the shoulder or upper part of the back; or which penetrate the neck from front to back and from above downwards, traversing the upper part of the neck and face. These vessels may also be wounded by splinters from a comminuted fracture of the clavicle. Walther saw a case of injury to the subclavian vessels after simple fracture of the clavicle by the base of a shell.

Lacerated wounds of the vessels at the base of the neck usually cause death from hæmorrhage on the battlefield, and for this reason they are rarely observed in field ambulances. Up to the present only a few cases with small skin wounds have come under observation.

Occasionally the vascular lesion is marked by copious internal hæmorrhage. This occurs when, simultaneously with the vessel, the dome of the pleura is wounded. Hæmorrhage is sometimes so profuse as to interfere with the action of the thoracic organs. Occasionally the intra-pleural pressure is sufficient to arrest the hæmorrhage, and the patient survives. Among seven cases of wounds of the subclavian vessels collected by Makins from the British Army returns, there was hæmothorax in two cases, and both patients survived. I have already mentioned a case of my own in which a wound of the subclavian vein opened into the pleura; hæmorrhage was not arrested until both ends of the vein had been tied and the pleural wound sutured.

In the absence of a pleural wound the hæmorrhage takes place into the cellular tissue at the base of the

neck. The arterial or arterio-venous hæmatoma which forms at the base of the neck spreads either towards the median line, forming a supra-sternal tumour; or towards the base of the neck, forming a supra-clavicular swelling. Occasionally the tumour pushes the sterno-mastoid upwards and backwards and reaches the upper part of the neck, extending to the hyoid bone or the mandible. Or it may be diffused either downwards beneath the clavicle into the axilla, or backwards beneath the trapezius and into the upper dorsal region.

Cases occur in which neither hæmatoma nor hæmorrhage is present. A dry wound of the subclavian artery is rare, but it is occasionally observed. Makins has described a case in which complete division of the third portion of the subclavian artery resulted in only an insignificant hæmothorax. The central end was retracted between the scaleni, and arrest of hæmorrhage occurred spontaneously. Amputation of the arm was necessitated by gangrene. In another case described by the same author the wound in the subclavian was blocked by a fragment of shell; removal of the fragment was followed by formidable hæmorrhage which was not immediately controllable, and the subject died. The immediate formation of a connection between the artery and vein may from the first exclude hæmorrhage. Makins describes two cases of this type.

Wounds of the vessels at the base of the neck are frequently accompanied by lesions of the neighbouring nerves and plexuses (brachial plexus, phrenic nerve, cervical sympathetic). The nervous lesions give rise to complete or partial anæsthesia and paralysis of the arm, symptoms of irritation and paralysis of the

diaphragm, ocular disturbance, etc. It has happened that, in the absence of supra-clavicular swelling, attention has been confined to the paralytic symptoms in the arm, the vascular lesion being discovered only at the operation. Makins saw a case of complete brachial monoplegia due to a wound by a bullet which grazed the upper border of the clavicle. There was no hæmorrhage, either external or internal. Suspecting no more than a nervous lesion, he made an incision over the clavicle in order to expose the roots of the brachial plexus. He found that the second portion of the subclavian artery had been divided; the upper end had retracted beneath the anterior scalene and was obliterated, while the lower end had retracted beneath the clavicle.

If untreated, wounds of the large vessels at the base of the neck almost invariably prove fatal. Death may occur very suddenly as the result of reactionary hæmorrhage, either externally or into the pleura. When a hæmatoma is present, death may result from its sudden enlargement with compression of the structures in the vicinity—the axillary vein, the collateral branches of the artery, and the nerves and structures at the base of the neck (pneumogastric and phrenic nerves, trachea and œsophagus). The direct results of this pressure may be gangrene of the arm, or functional derangement according to the structure compressed. The hæmatoma may become so large that it ruptures, either externally by way of the wound, into the pleura, or into the œsophagus or trachea. But here as elsewhere, the great source of danger lies in the infection of the wound, involving as it does formidable secondary hæmorrhage, which may result in death within a few seconds.

The therapeutic indications are in accordance with the nature of the lesion.

Lacerated wounds are even less frequently observed at the base of the neck than in the middle and superior regions.

I have already referred to the fact that, under exceptional circumstances, one might be called upon to arrest reactionary hæmorrhage from a lacerated wound of the neck, either during transport or upon arrival of the patient at the aid-post. In the case of hæmorrhage from a wound in the supra-clavicular region an attempt should be made to compress the subclavian vessels upon the first rib by pressing the fingers hard down in the direction of the first rib behind the clavicle (fig. 49). If the hæmorrhage continues, a pad should be applied as tightly as possible to the wound, or the cutaneous wound should be temporarily closed by one or more clamps until the patient can be got to the surgeon.

FIG. 49.—Digital compression of the subclavian. (After Farabeuf.)

Most frequently, if not invariably, however, the wounds at the base of the neck which reach the ambulance surgeon are narrow perforating wounds. Here again the indications for treatment vary with the nature of the projectile—in other words, with the likelihood of infection. When it is a wound by a shell-fragment, there is no doubt as to the right course to adopt. Operation, and immediate

operation, is indicated. In the case of a bullet-wound with punctiform orifices we are on more debatable ground. Nevertheless I am of opinion that here also the method of choice is early operation.

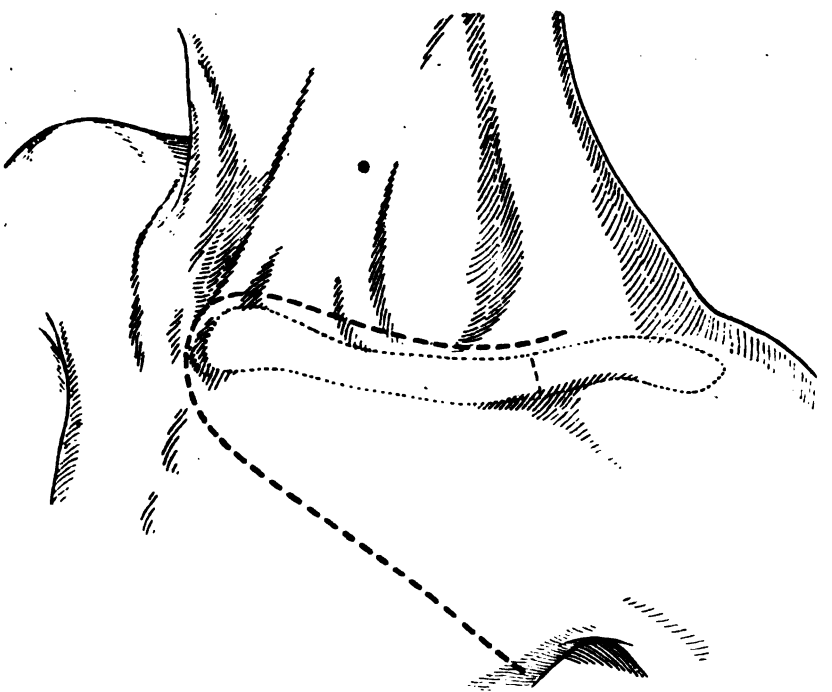

FIG. 50.—Skin incision for exposure of the large vessels at the root of the neck.

The method of access to the large vessels at the root of the neck, and the treatment of the vascular wounds when exposed, will now be described.

1. *Method of access to the great vessels at the root of the neck.*—All surgeons who have had to operate upon the vessels at the base of the neck are agreed that it is essential to expose them very freely. The principal obstacle to exposure is the clavicle, with the sterno-

mastoid muscle above it and the pectoralis major below. The idea of resecting the bone and dividing

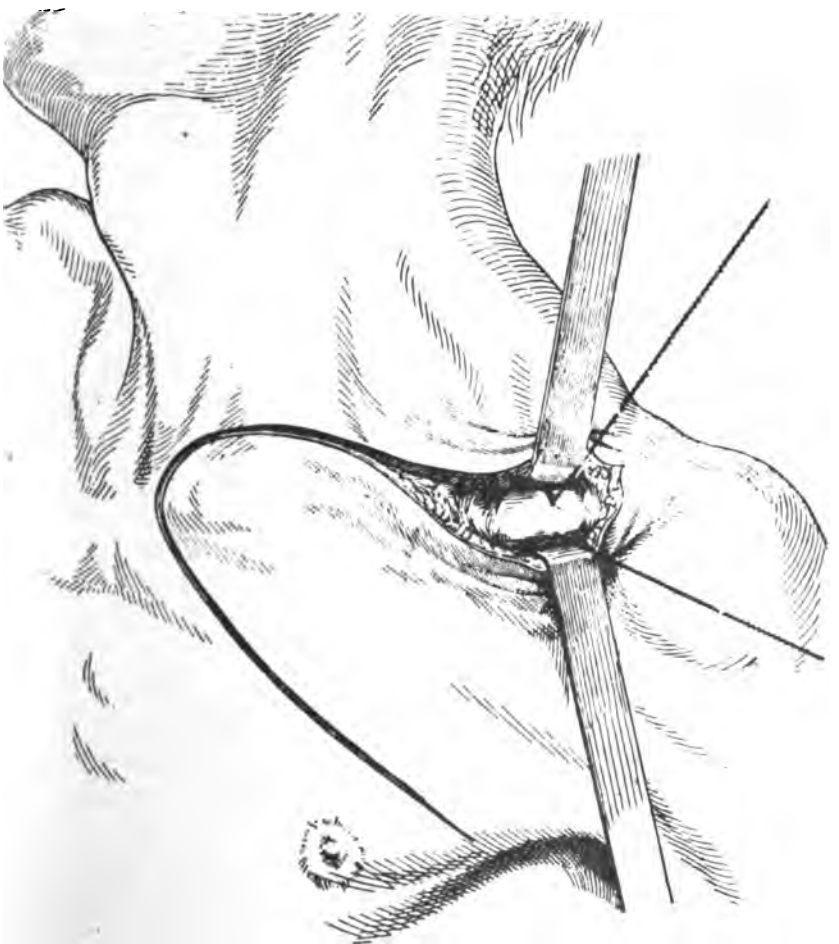

Fig. 51.—Section of the clavicle.

the muscles is not a new one. The following method, which is little known in France, presents very great advantages :—

Two fingers-breadths above the clavicle a horizontal

incision is made, parallel to its upper border and running from its outer third to an inch beyond the sterno-clavicular joint of the same side (fig. 50). The clavicle is exposed at the outer end of this incision, and is divided at the junction of the middle with the outer third by means of a Gigli's saw (fig. 51). At the inner end of the incision the clavicular head of the sterno-mastoid is divided and the sterno-clavicular articulation exposed. The joint is opened and the sternal end of the clavicle is completely disarticulated, leaving the inter-articular fibro-cartilage adherent to the sternal surface. The skin incision is now continued from its inner end in a curve downwards and outwards towards the axillary fold in such a way as to trace out a large flap with a broad external base. The skin and cellular tissue are divided, together with the pectoralis major, which is cut across about an inch from its costal origin; deeper still, the pectoralis minor is divided close to its thoracic origin. The nerves to the pectoralis major and pectoralis minor are left intact, and are lifted with the muscles in the flap. The loose portion of the clavicle is raised with the flap, and is turned outwards. The large vessels are now admirably exposed (fig. 52). At the upper and inner part of the wound the sternal extremity of the first rib is seen, upon which lies the subclavian vein and, immediately internal to it, the junction of the jugular with the subclavian vein. Close to this point is the vertebral vein, running from above downwards and from behind forwards. Immediately outside this vein, and separating it from the subclavian artery, is the scalenus anticus muscle. The anterior surface of this muscle is crossed by the transverse scapular artery and the phrenic nerve. Immediately internal to the

muscle the first or ascending portion of the subclavian, with its branches, the vertebral and thyroid

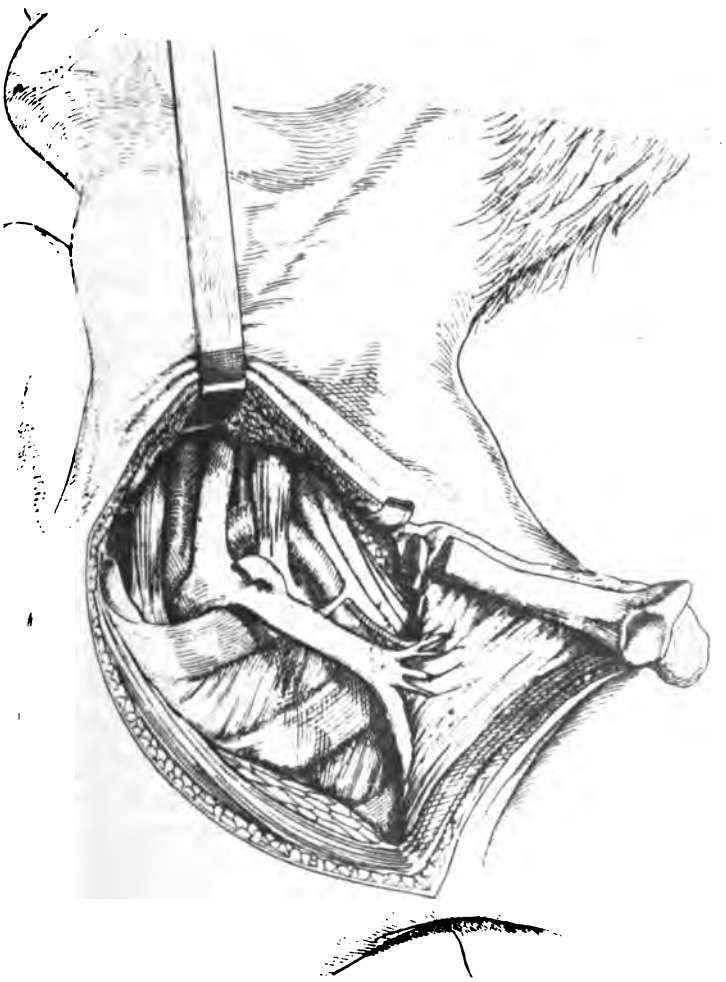

FIG. 52.—The great vessels at the root of the neck.

axis, is seen. Beyond it the origin of the common carotid is visible, and deep in the wound is the innominate artery.

Exposure of the region in this manner gives free access to the origin of the common carotid, the three parts of the subclavian, and to some degree to the innominate artery. To expose the latter more completely, half of the inter-clavicular notch should be resected. Section of the manubrium may, if preferred, be performed at an earlier stage of the operation, and in that case the resected portion is turned back with the resected portion of the clavicle without disarticulation.

2. *Treatment of the exposed vascular lesion.—The first stage of the operation* consists in temporary arrest of hæmorrhage by a ligature or an artery-clamp placed on the proximal side of the wound. An exact knowledge of the site of injury is essential; it is, however, frequently very difficult to obtain.

Certain guides are provided by the clinical examination. A hæmatoma without murmur or pulsation is a venous hæmatoma, due to lesion of the subclavian vein or of a tributary of the jugulo-subclavian. A large pulsatile hæmatoma, the principal extension of which is towards the neck, which presents a murmur which is transmitted towards the parotid, and which suppresses the temporal pulse, is probably due to a wound of the lower part of the common carotid. A hæmatoma which develops chiefly in the direction of the subclavian hollow, extends beneath the clavicle, presents a murmur which is transmitted towards the axilla, and suppresses the radial pulse, is probably of subclavian origin. But the clinical appearances are by no means always clear and well defined, and in the majority of instances clinical examination does not establish a diagnosis. Even after free exposure of the site, it is frequently difficult to detect the

bleeding point. Under such circumstances how is temporary arrest of hæmorrhage to be effected?

Carefully, slowly, and with infinite precautions the upper and inner part of the field of operation is dissected out, until the common carotid, the first portion of the subclavian, and the innominate artery are disclosed. Diagnosis is effected by compression of each artery in turn until the hæmatoma ceases to pulsate. The vessel in question is immediately controlled, and hæmorrhage during operation is thus excluded. This is the first, indispensable, stage of the operation.

The next step is the free incision of the hæmatoma. The clots are rapidly evacuated, and the site is well cleaned and plugged. The plugs are removed one by one, when the vascular lesion is readily detected.

In the case of a single wound of the subclavian vein or of the jugulo-subclavian junction the vessel is calmly and steadily dissected out, and a ligature is placed above and below the wound in the vessel. Where dissection and isolation of the venous trunk is a matter of difficulty, in certain exceptional cases the wound in the vein may be closed by forceps left *in situ*. Ligature and forci-pressure are the two methods most commonly employed. Suture of a large venous trunk such as this is not a difficult matter, but I do not believe that anything is gained by it. In one case of supra-clavicular and supra-sternal hæmatoma Pauchet exposed a wound behind the clavicle on the inner aspect of a large venous trunk which he took to be the innominate artery, and which he successfully sutured. For my own part, I regard venous suture, here as elsewhere, as a useless

operative complication. In so far as air-embolism is concerned, an accident which was formerly much dreaded, I can only say that it has never come under my observation.

In the case of a wound of the subclavian artery the vessel is dissected out and ligatured above and below the wound. This double ligature is placed either outside, between, or inside the scaleni. The method may necessitate division of the scalenus anticus; in that case care must be taken to avoid the phrenic nerve, which crosses the anterior surface of the muscle and then runs down its anterior border. Ligature of the subclavian artery does not as a rule endanger the vitality of the limb. The number of the collateral branches of this vessel assures the re-establishment of the circulation, and gangrene is exceptional. Out of sixteen cases of ligature of the subclavian artery collected by Monod and Vanverts in 1911, gangrene of the arm occurred in one case only. Makins reports that out of seven cases of injury of the subclavian diagnosed or operated upon in the British Army since the war, in one case only did gangrene occur. Out of eight cases operated upon in the German Army in the last two years, there was in one case partial gangrene of the fingers (Lexer). Soubbotitch has ligatured the subclavian four times and Duval twice without complication. Le Jemtel's case developed gangrene, but here the hæmatoma was infected, and his operation was for secondary hæmorrhage.

The comparative harmlessness of ligature of the subclavian justifies the exclusion of lateral and circular suture. In the case of a small lateral wound, however, lateral suture is perhaps advisable. In the case of

a large wound demanding circular suture, the method is never permissible.

The wound of the subclavian artery is not infrequently accompanied by injury of one of its branches —the vertebral, thyroid axis, or the internal mammary. Before it passes between the scaleni muscles, the subclavian artery gives off numerous branches, which, as a matter of fact, are more exposed to injury than the trunk itself. The multiplicity of these vascular wounds may render operation extremely difficult. In spite of preventive measures, the blood escapes profusely from the wound, and complete arrest of hæmorrhage may become an extremely complicated matter.

Finally, hæmatoma at the base of the neck may be due to an isolated wound of a branch of the subclavian, more especially of the vertebral artery. Pre-operative diagnosis of this lesion is practically impossible, and operative diagnosis is very difficult. As a general rule it is only by compression of the common carotid and the subclavian that the pulsation of the hæmatoma is ultimately referred to the vertebral. Error is very frequent. Monod and Vanverts have collected eighteen cases of surgical intervention in hæmatoma at the base of the neck due to lesion of the vertebral. In nine cases the common carotid was ligatured in error and the patient died. In one case the vertebral was successfully tied. In the eight remaining cases the hæmatoma was first opened, and in five of these plugged, with death in three cases and recovery in two. In three cases ligature or forci-pressure of the vertebral was employed, and all these cases recovered. Since the war I know of only Soubbotitch's case, in which

the vertebral was ligatured after incision of the hæmatoma, death following as the result of primary hæmorrhage.

The difficulties of operation—namely, the multiplicity of the vascular wounds and the difficulty of controlling the hæmorrhage—combine to render the free opening of a hæmatoma at the base of the neck an operation of extreme gravity. Among eight cases operated upon in the German Army since the war, there were three post-operative deaths. At the German Medical Congress in 1915, Bier reported upon the first hundred cases of operation of arterial hæmatoma since the war. There were eight post-operative deaths, and of these four were cases of hæmatoma at the base of the neck. Hence the fear of primary hæmorrhage has induced a certain number of surgeons to reject incision of the hæmatoma in favour of proximal ligature. Duval adopted the method in two cases. It is certain that, generally speaking, this method is infinitely less effectual than incision and ligature in the wound. Is it less dangerous? Out of sixteen subclavian hæmatomata collected by Monod and Vanverts before the war, four were treated by proximal ligature with two deaths, eleven by incision and direct hæmostasis with three deaths. These figures speak in favour of the latter method, and although the number of observations since the war is very small, I am convinced that, if carried out in the manner which I have described, incision and ligature in the wound constitutes, here as elsewhere, the method of perfection.

B. ANEURISM AT THE ROOT OF THE NECK

Traumatic aneurism at the root of the neck is extremely rare. It is due either to a lesion of the innominate, carotid, or subclavian arteries at their origin, or to lesion of the two latter vessels some distance beyond it.

In aneurism of the first type the tumour develops immediately above the clavicle and extends downwards, upwards, and backwards. In a case which I saw with M. Bérard, and which is shown in figs. 1 and 2, Plate II., the tumour extended downwards beneath the clavicle and upwards to the extreme upper part of the neck. The infiltration was continued backwards beneath the trapezius, forming a posterior prolongation which extended to the angle of the scapula. The apparent dimensions of the tumour are not always as large as this. In such cases the effusion of blood downwards may result in the formation of a thoracic tumour. In many of these cases it is practically impossible to define the outline of the tumour and arrive at the precise situation of its upper pole. In other words, there are practically no clinical means of determining whether the aneurism originates in the innominate artery or the first part of the common carotid or subclavian.

In aneurism of the second type the tumour is more circumscribed. If of carotid origin, it develops vertically towards the neck, in front of the sterno-mastoid, above the supra-sternal fossa. If of subclavian origin, it develops in the supra-clavicular space towards the shoulder and below the clavicle.

The surgical treatment of aneurism at the root of

the neck is an extremely difficult undertaking. From this point of view a distinction must be drawn, however, between isolated aneurism of the common carotid and subclavian, and deep-seated aneurism at the origin of these vessels or of the innominate artery.

In the latter case the usual method by extirpation of the aneurismal sac is impracticable in the great majority of cases. This operation involves, as a preliminary step, the exposure of the cardiac pole of the aneurism and the temporary ligature or clamping of the afferent arterial trunk. The dissection of the sac should only be undertaken after this. Now it is extremely difficult, if not impossible, to approach the proximal pole of the tumour from this point. The large incision described above gives access to the middle part of the innominate artery and permits of its ligature. But to isolate behind the sternum the cardiac pole of an aneurism, the wall of which is not only behind the great trunk of the innominate vein, but may also be adherent to the trachea or to the mediastinal pleura, is an operation of extreme peril, and one which may terminate badly. For this reason the ideal method, namely, extirpation, is not indicated in the rare case of aneurism at the root of the neck.

Arterial ligature, usually inferior to extirpation, is here the sole method possible. The ligature may be placed either proximal to the aneurism on the innominate artery, or distal to it on the common carotid, the third portion of the subclavian, or on both.

When the aneurism is supra- or retro-sternal, proximal ligature of the innominate artery, or of the carotid and subclavian arteries near their origins, is

FIGS. 1 and 2.—Arterial aneurism at the base of the neck.
(Unpublished photograph by Bérard.)

FIG. 3.—Fracture of the mandible. Division of both internal and external carotids by a bullet. (Latarjet's case. Val-de-Grâce Museum.)

PLATE II.

an extremely dangerous procedure which has been attended by disastrous results. Monod and Vanverts collected five cases, of which four ended fatally. These figures are not encouraging.

For this reason distal ligature is the method adopted in the vast majority of cases. The ligature may be placed at a suitable spot upon the carotid or subclavian, or simultaneously upon both vessels. In the latter case the vessels are ligatured at the same operation, beginning with the carotid. By adopting this sequence cerebral embolism, due to the back-eddy of the blood in the aneurism after ligature of the subclavian, is excluded. It is hardly necessary to point out that this method is infinitely less dangerous than proximal ligature. Monod and Vanverts have collected sixty-five cases of distal ligature in which the mortality did not exceed 15 per cent. The actual figures are as follows: permanent improvement, 30 per cent.; permanent cure, 22 per cent.; operative failure ending in death, 30 per cent.

Isolated aneurisms of the common carotid immediately above the sternum, and of the subclavian outside, between, or immediately inside the scaleni, are very much more amenable to surgical treatment.

Carotid aneurism has already been dealt with. Subclavian aneurism, whether arterial or arterio-venous, is best treated by extirpation. The operation includes the free exposure of the vessel by raising an osteo-cutaneous flap in the manner already described, ligature of the artery immediately above and below the tumour, and the removal of the sac. To the seven cases of extirpation collected by Savariaud in 1906, Monod and Vanverts in 1910 added four. Of these eleven cases, ten recovered and

one died. Traumatic aneurism of the subclavian from wounds produced by projectiles of war is, however, so rare, that no case of extirpation of such an aneurism has come to my notice since the outbreak of war.

A large number of surgeons have, however, remained faithful to the method by ligature, either simple proximal ligature or ligature above and below. The proximal ligature may be placed either outside, between, or immediately inside the scaleni. The simplest and least dangerous operation is extra-scalenic ligature. Monod and Vanverts describe ten cases, with nine recoveries and one relapse. Inter-scalenic ligature appears to be equally favourable. The same authors describe six cases in which the method was employed, with five recoveries and one death. Inter-scalenic ligature, on the other hand, is far more difficult of execution. Owing, moreover, to the fact that it destroys the branches, it endangers the circulation of the arm. In ten cases collected by Monod and Vanverts there were two deaths. Since the war the operation has been performed without complication by Duval, who ligatured the first part of the subclavian. Soubbotitch operated successfully upon an arterio-venous aneurism of the subclavian vessels; he employed double ligature of the artery and lateral suture of the venous wound.

CHAPTER V

WOUNDS OF THE VESSELS OF THE AXILLA

WOUNDS OF THE AXILLA

Wounds of the axillary vessels are more often seen in the field ambulances than wounds of the subclavian or the carotid. Eleven cases of the kind have come under my own care.

In some instances there is a large gaping wound of the shoulder or of the axilla, entirely filled with clots beneath which the hæmorrhage has become spontaneously arrested. It may even happen that in extensive destruction of the shoulder or after an arm has been torn off, the vessels are seen in the stump widely gaping, but not bleeding. I have on several occasions seen the arm almost completely severed from the trunk with the skin much torn in the neighbourhood of the axilla, and in the wound the axillary vessels lay stretched and ruptured but completely dry.

The majority of lesions are, however, perforations by bullets or shell-fragments. In such cases there may be internal hæmorrhage into the pleura, or interstitial hæmorrhage with the formation of an axillary hæmatoma. In exceptional cases there is little or no hæmorrhage.

operative complication. In so far as air-embolism is concerned, an accident which was formerly much dreaded, I can only say that it has never come under my observation.

In the case of a wound of the subclavian artery the vessel is dissected out and ligatured above and below the wound. This double ligature is placed either outside, between, or inside the scaleni. The method may necessitate division of the scalenus anticus; in that case care must be taken to avoid the phrenic nerve, which crosses the anterior surface of the muscle and then runs down its anterior border. Ligature of the subclavian artery does not as a rule endanger the vitality of the limb. The number of the collateral branches of this vessel assures the re-establishment of the circulation, and gangrene is exceptional. Out of sixteen cases of ligature of the subclavian artery collected by Monod and Vanverts in 1911, gangrene of the arm occurred in one case only. Makins reports that out of seven cases of injury of the subclavian diagnosed or operated upon in the British Army since the war, in one case only did gangrene occur. Out of eight cases operated upon in the German Army in the last two years, there was in one case partial gangrene of the fingers (Lexer). Soubbotitch has ligatured the subclavian four times and Duval twice without complication. Le Jemtel's case developed gangrene, but here the hæmatoma was infected, and his operation was for secondary hæmorrhage.

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plenty of room in the direction of the axilla. The simplest plan is to cut across the entire anterior wall of the axilla.

A horizontal incision is made along the lower border

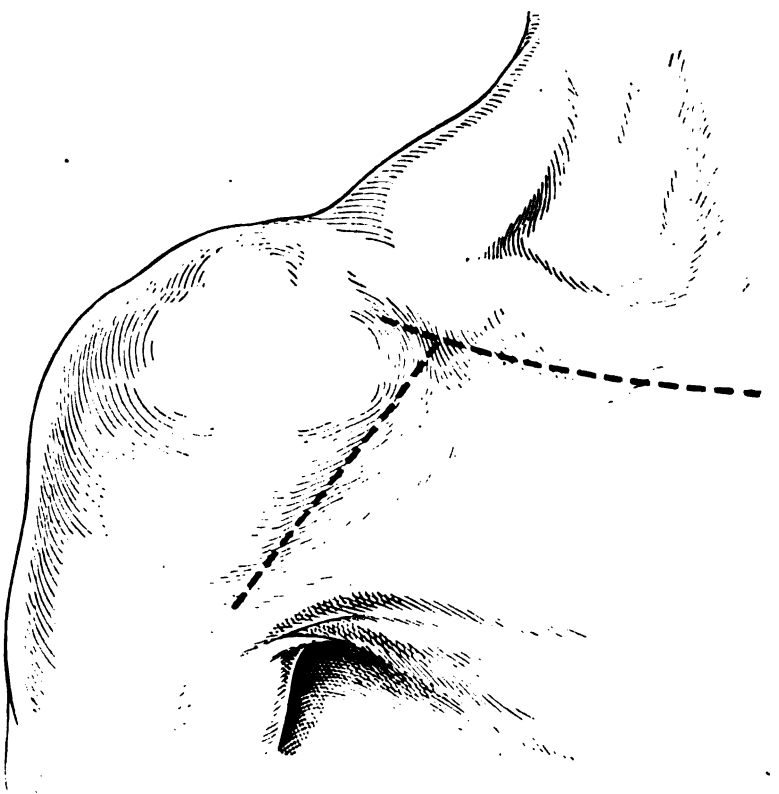

FIG. 53.—Skin incisions for exposure of the axillary vessels.

of the clavicle from the coracoid process externally to within an inch of the sterno-clavicular articulation internally. The skin and the cellular tissue are incised; the anastomosing veins between the cephalic and the external jugular are tied, and the clavicular fibres of the pectoralis major divided down to the fascia running

from the clavicle to the thorax and axilla. This fascia is cut through, care being taken to incise it over the subclavian, which it encloses. The lower lip of the incision is turned back, revealing the axillary artery as it emerges from beneath the middle of the clavicle.

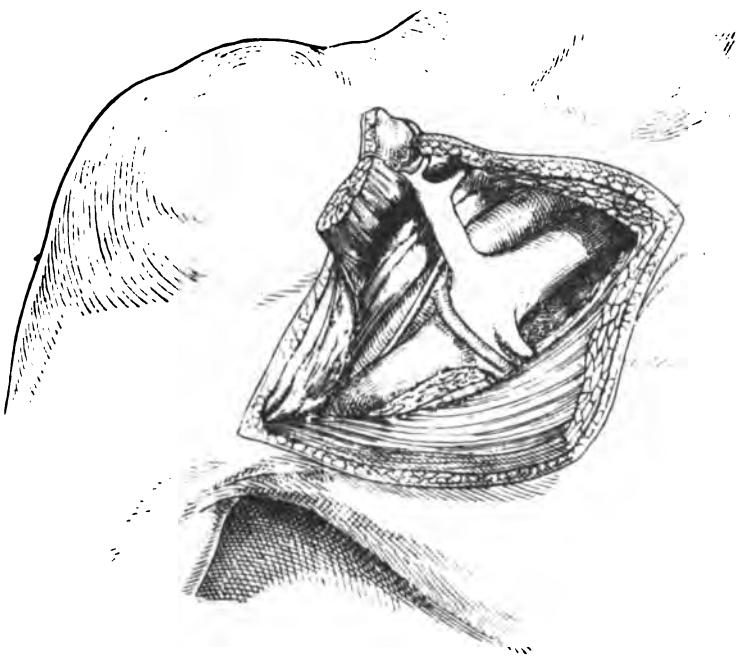

FIG. 54.—Exposure of the great vessels of the axilla.

It is now easy to isolate the artery and raise it on a thread.

From the outer end of the transverse incision an oblique incision is now made downwards and outwards. It follows the groove between the deltoid and pectoralis major, and runs down to the lower border of the latter muscle (fig. 53). The cephalic vein and the acromio-thoracic artery are retracted outwards; the pectoralis major and minor are divided

transversely, care being taken to avoid their vessels and nerves, which are retracted either outwards or inwards. The axilla is now completely exposed, and its vessels and nerves are readily accessible (fig. 54).

2. Treatment of the Vascular Injuries disclosed.—The sac is freely opened, the clots removed, and the wound dried. The wound of the vessel is now visible, and may be in the axillary artery, in the artery and vein, or, more rarely, in one or more branches of the former.

If there is a wound of the axillary artery, should double ligature be performed, or should suture be attempted?

It is an axiom that ligature of the axillary artery does not in itself endanger the circulation of the limb, provided always that the vessel is not tied at its lower end immediately below the circumflex branches. The branches given off above this point are so numerous that, in whatever part of the vessel the ligature is applied, the circulation below is rapidly re-established. At the lower end of the vessel, on the contrary, the sole collateral is a small anastomotic branch running from the circumflex to the profunda. Hence ligature at this point is regarded as extremely dangerous. Bearing in mind the harmlessness of ligature of the axillary in general, it is obvious that the choice of the precise method of treatment must be largely influenced by the site of injury. If this be in the middle part of the artery, the two ends of the vessel may be safely tied in the wound. If it be in the lower part, lateral suture should be performed for a lateral wound, and circular suture for complete division where possible. Recourse should only be had to ligature when circular suture is impracticable.

Before the war Monod and Vanverts collected eighteen cases of free incision of an axillary hæmatoma with double ligature in the wound. The results included fourteen recoveries, three cases of gangrene, and three deaths. As far as could be gathered from the histories of the cases, the three cases of gangrene occurred after ligature of the lower end of the artery. Since the war a certain number of operations of this kind have been done at the front. I have performed immediate operation in eleven cases. In six, there were either large lacerations, or punctured wounds accompanied by a small hæmatoma or without hæmatomata. In no case did complications arise, though in two at least the lower part of the vessel was tied. In one case there was severe contusion of the artery with extensive thrombosis. The limb was swollen and cold; gangrene was imminent, when the patient died from a pulmonary lesion. On one occasion, one of my assistants operated for extensive laceration of the vessels by a bullet fired point-blank. Double ligature was not immediately followed by any complication, but on the sixth day secondary hæmorrhage took place, and the patient died while I was transfusing blood into his veins. I also operated upon three enormous axillary hæmatomata. In one case, in which a double ligature was placed upon the lower end of the artery, there was rapid gangrene of the hand and forearm, which necessitated amputation of the arm above the elbow. The patient recovered. The compression by the hæmatoma of the only anastomotic communication of the lower part of the vessel renders the re-establishment of the circulation extremely hazardous, and greatly increases the chances of gangrene. Out of twenty-five cases of operation

for axillary hæmatoma published since the war, there were five cases of circumscribed or extensive gangrene, that is to say, 25 per cent.

Suture of the axillary artery was performed in a certain number of accidental wounds before the war. Monod and Vanverts describe fifteen cases, twelve of lateral, three of circular suture. In all cases the results were excellent. As far as my knowledge goes, neither lateral nor circular suture of the axillary artery has been performed immediately after injury since the war. It is evident from this that in the vast majority of cases vascular contusion and other causes, which have already been described, combine to render this suture a matter of extreme difficulty. Nevertheless, my own opinion is that lateral suture is indicated for small wounds of the lower end of the vessel.

ANEURISMS IN THE AXILLA

Traumatic aneurisms in the axilla are, as a general rule, arterio-venous. Makins has, however, observed five cases of the arterial variety.

Arterial or arterio-venous aneurism in the axilla shows itself as a circumscribed tumour, which either pushes up the anterior fold of the axilla or pushes down its base. The tumour is fixed, more or less soft, and pulsates; the arterial or arterio-venous murmur is very distinct. It is almost invariably accompanied by circulatory and nervous troubles in the arm, forearm, or hand. In the majority of clinical histories it is remarked that the hand and forearm are cold and cyanosed, and that the sensation and movements of the fingers are affected either as a whole or in the areas supplied by one of the nerves (median, ulnar, radial).

Trophic, vasomotor, secretory, and sensory derangements are observed with quite special frequency. Their association has been studied by Leriche, and his results have recently been published in an excellent work by Mme. Athanassio-Benisty.

The skin of the hand is either smooth, shiny and tense, or dry and scaly; eruptions and ulcerations are frequent. The nails are uneven, furrowed, and irregular in shape. The hairs are scanty and poor. The cellular tissue presents a species of hard, elastic, sub-dermal infiltration, resembling that of chronic trophœdema. The muscles are sometimes the seat of a fibrous and fibro-sclerotic degeneration, which may be accompanied by retraction of the tendons. In such cases the hand may assume the classic attitude characteristic of Volkmann's ischæmic paralysis. The joints become stiff, and in time the bones may become deformed.

The vasomotor disturbances are shown by a red-violet discoloration of the skin of the hand, and by a lowering of the local temperature.

The secretory and sensory derangements are diminution of local perspiration and pain. The pain is sometimes extremely severe, and gives the patient no rest. According to Leriche, it is due to inflammation of the peri-arterial sympathetic plexuses. There is also a certain degree of disturbance of objective sensation, which is manifested by complete anæsthesia of a varying region entirely unrelated to the distribution of the peripheral nerves.

The ideal method of treatment of axillary aneurism is by extirpation. Monod and Vanverts describe fourteen cases, in all of which recovery was complete. All surgeons insist upon the necessity for minute and

very careful dissection of the sac, in the wall of which the median, ulnar, and radial nerves are all more or less intimately incorporated. This care forms the chief surgical difficulty, but it is also the factor that lends to operation the whole of its therapeutic value.

Proximal ligature of the artery, formerly the method of choice, has to-day fallen almost entirely into disuse. A few surgeons still tie the subclavian; but this allows the sac to persist, and fails to relieve the pain, trophic derangement, and paralysis. For this reason it should be abandoned in favour of extirpation.

The method of treatment *par excellence* of arterio-venous aneurism is by extirpation of the anastomosed arterio-venous segment. In the case of aneurismal varix, resection as close to the communication as possible is indicated. Where a sac is present it should be completely dissected out, care being taken to release the nerves by which it is surrounded (heads of the median, the ulnar, and the internal cutaneous).

Removal of the aneurism leaves an arterial or arterio-venous wound, which may be treated either by double or quadruple ligature, or by reparative suture.

Ligature of the vein and the artery is a comparatively safe method of treating these aneurisms. The establishment of the collateral circulation materially reduces the danger of ligature of the lower end of the axillary, but does not altogether do away with it. Mériel's case, in which ligature was followed by partial gangrene of the fingers, is an instance in point. Even when there is no gangrene, motor troubles in the arm, the outcome of defective circulation, frequently persist; the circulation is just sufficient to assure the

nutrition of the arm, but not its perfect function. This is the explanation of the fact that, in certain cases, there is persistent paresis of the limb, a certain degree of general loss of power which is not always accounted for by the nature of the nervous lesions. It is essential that the functions of the arm and hand shall remain intact, and gangrene is not the only possibility which it is necessary to take into consideration. If examination by the various methods which have been described in connection with aneurism in general seems to show that perfect re-establishment of the circulation is doubtful, lateral or circular arterial suture should be attempted.

Ligature has been performed in France in a certain number of cases since the war. Quénu, Mériel, Mauclaire, Duval, Bérard, have all extirpated arterio-venous aneurisms of the axilla and ligatured the ends of the vessels. Their patients have not only recovered, but the nervous troubles have largely disappeared. One of Mauclaire's cases is interesting from the fact that the subclavian had been tied without result six months previously. Surgeons other than the French are more generally in favour of complete repair of the vessels. Soubbotitch describes his treatment of eight axillary aneurisms. Of these seven were arterial aneurisms, which he treated by extirpation and ligature, with five recoveries and one death. He employed lateral and circular suture each once, and both cases recovered. In one case of arterio-venous aneurism he employed circular suture of the artery and ligature of the vein; the patient recovered. Out of four arterio-venous aneurisms of the axilla treated in the German Army, the results of which I was able to ascertain, in two cases circular

suture of the artery and ligature of the vein was employed, both recovering; two cases were treated by venous grafts after resection of a large portion of the artery, and both recovered. In both instances the venous graft was taken from the cephalic vein. These results must be regarded as extremely encouraging, and they confirm the views which I expressed above. As a general rule, then, ligature is indicated; but when there is reason to doubt the complete re-establishment of the collateral circulation of the limb, suture may be employed—indeed, it ought to be employed—wherever it appears easy or even possible.

CHAPTER VI

WOUNDS OF THE VESSELS OF THE ARM, FOREARM, AND HAND

Wounds of the principal trunks of the arm; forearm, and hand are extremely frequent.

Wounds of the arm, with or without fracture of the humerus, frequently affect the brachial or the superior profunda in the musculo-spiral groove (fig. 55). Such wounds produce either severe external hæmorrhage or a diffuse hæmatoma of the arm. The frequency of external hæmorrhage would be considerable if it included all the cases in which a tourniquet has been applied to the arm. In the majority of instances, however, the tourniquet is superfluous, its removal at the dressing station being followed by no bleeding from the wound; a simple venous flow has been mistaken for arterial hæmorrhage, frequently with disastrous results. In an earlier chapter I pointed out the danger of the tourniquet. On more than one occasion I have seen rapid gangrene of the arm result from the prolonged application of a tourniquet which the absence of any arterial wound rendered superfluous. A tourniquet should be employed only in cases where there is unmistakable arterial hæmorrhage which is not arrested by plugging

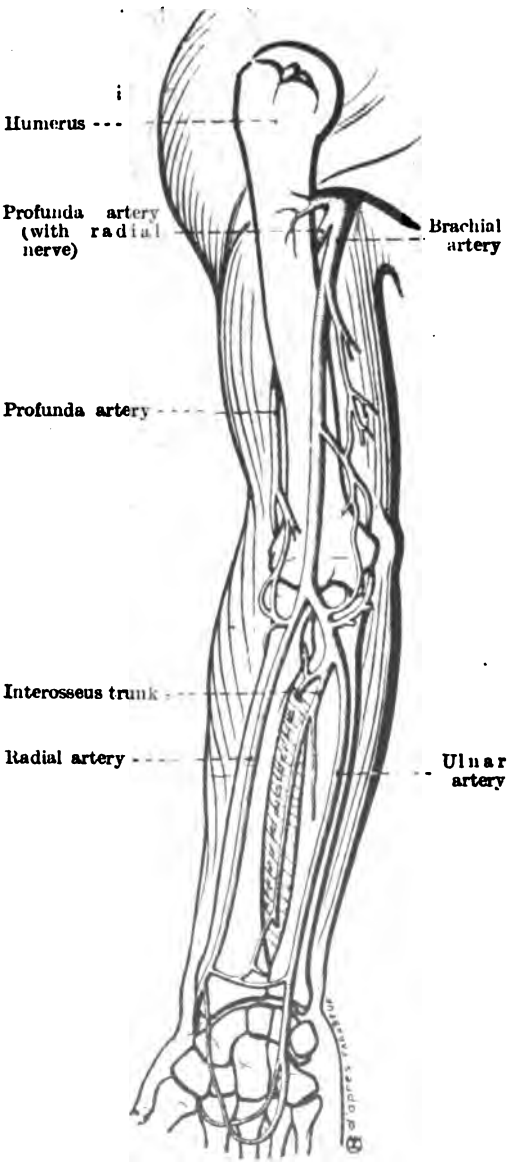

Fig. 55.—Arterial topography of the upper limb. (Broca.)

(fig. 56). When a tourniquet is employed the patient should be got at the earliest possible moment to a field ambulance, and there direct hæmostasis in the wound should be at once secured.

Diffuse hæmatoma anywhere in the arm is frequent. It has no surgical interest, however, unless it is situated in the extreme upper end of the limb and proceeds from an arterial wound between the origin of the circumflex and the superior profunda. Here the anastomoses are very scanty, and should the hæmatoma attain dimensions sufficient to compress the neighbouring

vessels, gangrene of the arm is a possible termination. Two such cases have been described by Murard. It should be noted, however, that the gangrene in these two cases was both mechanical and septic—a variety in the etiology of which infection is a preponderating factor.

Lower down the arm the anastomoses are numerous. At the elbow they form a peri-articular net-

FIG. 56.—Digital compression of the brachial artery. (After Farabeuf.)

work of considerable importance. It follows that ligature of the main trunk at this point is of only slight importance, for the circulation of the arm is assured in advance. A further consequence of the complexity of the vascularisation of the arm and elbow lies in the frequent multiplicity of the vascular wounds. In addition to the brachial artery and vein, it may be necessary to tie the median basilic vein, one or more radial or ulnar recurrent, or the interosseus vessels. Arterial wounds of the arm are sometimes accompanied by nervous lesions. In association with a wound of the brachial artery there may be a

lesion of the median or ulnar nerve; in the case of the superior profunda, of the radial (musculo-spiral).

The clinical course of wounds of vessels of the arm is uneventful. All that has been said concerning the clinical development of aneurism in general and its therapeutic indications applies here. It is not necessary to recapitulate.

The method of exploring the brachial varies slightly according to whether the lesion is situated in

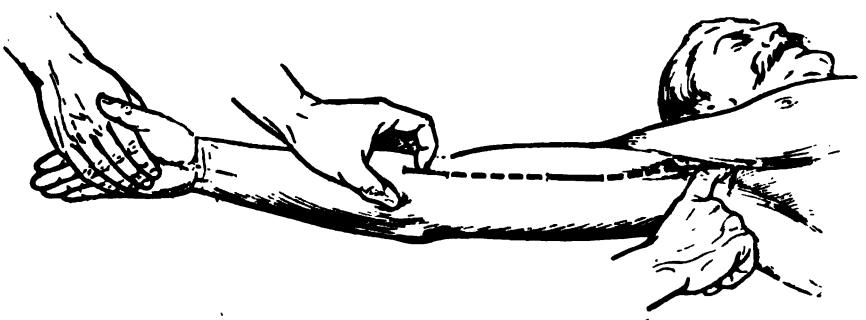

FIG. 57.—Line of the axillary and brachial arteries. (Broca.)

the upper and middle parts of the arm or at the bend of the elbow.

To expose the brachial at about the middle of the arm an incision should be made either along or slightly in front of the line of the vessel—in other words, a line running from the axillary apex to the middle of the bend of the elbow (fig. 57). The deep fascia is exposed and incised well over the biceps. The outer edge of the deep fascia is caught in the forceps, the biceps is freed, raised, and retracted upwards and outwards. Beneath a thin aponeurotic layer the vasculo-nervous bundle is seen, the median nerve in front, the artery behind it. The nerve is raised, and the brachial artery is then fully exposed.

To expose the artery at the bend of the elbow a slightly oblique incision is made from above downwards and from within outwards, the centre corresponding exactly to that of the ante-cubital fossa. Beneath the skin the median basilic vein is either divided or pulled inwards. The deep fascia is then divided, and the bicipital fascia is exposed; the artery is immediately beneath it. The fascia is divided, either directly or on a grooved director, and the artery is easily discovered between the tendon of the biceps externally and the median nerve internally.

When the vascular lesion has thus been exposed, should the vessel be ligatured or sutured? The dangers of ligature are so infinitely remote that there is no necessity to attempt suture. Before the war, gangrene after ligature of the brachial was unknown. Yet this vessel has been sutured more frequently than any other. Monod and Vanverts have published eighteen cases, thirteen of lateral and five of circular suture. In war practice I have ligatured the brachial six times without untoward result, and I know of twenty-five to thirty similar cases. Suture was once attempted, and abandoned by Duval. Soubbotitch has performed circular suture three times, and Hotz lateral suture once. In such cases as these the method does not appear to me to serve any useful purpose, and surgical complications which are not absolutely indispensable should always be avoided.

Wounds of the forearm and hand are frequently complicated by lesion of the ulnar or the radial. It is expedient to draw attention here to the frequency of diffuse hæmatoma of the upper part of the forearm. Owing to the deep-seated position of the

vessels in this region the blood is effused for some distance from the wound into the muscular interspaces. There is no tumour, *i.e.* no localised swelling, but there is a generalised swelling of the limb, which is easily recognised by an experienced

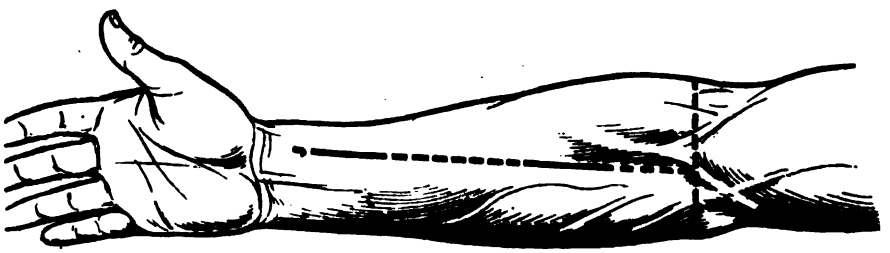

FIG. 58.—Ligature of the radial artery. (Broca.)

surgeon. Diffuse swelling with pain in wounds of the forearm is very suggestive. In nine cases out of ten these symptoms point to the presence of a diffuse hæmatoma, which should receive immediate surgical treatment if ischæmic and septic gangrene of the forearm and hand are to be prevented.

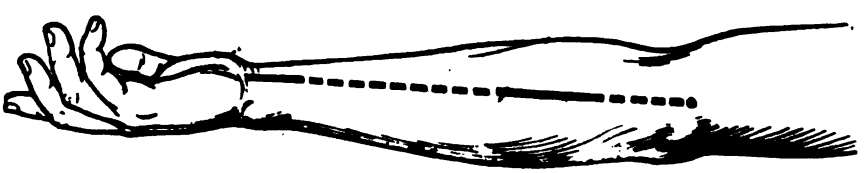

FIG. 59.—Ligature of the ulnar artery. (Broca.)

To expose the radial artery at the upper part of the forearm an incision should be made along a line running from the centre of the ante-cubital fossa to the line of the pulse (fig. 58). The upper end of the incision is three fingers-breadths below the ante-cubital fossa. The deep fascia is exposed and divided along the inner border of the supinator

longus, and the muscle is pulled outwards. In the space beneath the vessels are seen, covered by a thin aponeurotic layer from which they are readily freed.

To expose the ulnar artery the incision should follow a line running from the tip of the inner condyle to the outer border of the pisiform bone (fig. 59), commencing three fingers-breadths below the antecubital fossa. The deep fascia is exposed, the hand is extended in order to stretch the tendons and muscles, and an incision is made over the space between the flexor carpi ulnaris and the flexor sublimis digitorum. The incision is continued lightly across the flexor, which is recognised by the fact that, not being adherent to the aponeurosis, its fibres protrude through the incision. A grooved director is slipped into the space between the two muscles; relaxation of the muscles by flexion of the wrist relaxes the flexor and opens up the space. At the bottom of the space the ulnar nerve is seen, and between it and the axis of the limb, quite close to the nerve lying on the flexor profundus, is the artery.

Arterial and arterio-venous aneurisms of the arm, forearm, and hand are rarely observed at base hospitals. This is due to the fact that the class of injury from which these lesions proceed comes under early treatment at front-line stations. The symptomatology and therapeutics of these aneurisms possess no special points of interest, and are included under the heading of aneurisms in general.

CHAPTER VII

WOUNDS OF THE PELVIC VESSELS

DEEPLY buried as they are in the abdomino-pelvic cavity, the iliac vessels rarely present isolated uncomplicated wounds. Such wounds are usually complicated by fracture of the pelvis, or by a perforating wound of the abdomino-pelvic cavity—in other words, they are observed only in connection with extensive traumatic lesions, such as usually result in death on the battlefield. This is the explanation of their extreme infrequency at front-line stations. The immediate and formidable hæmorrhage is followed very rapidly by death, as in the case shown in fig. 5. Is it possible for a sub-peritoneal hæmatoma capable of arresting the hæmorrhage to form? The close relation of the vessels with the peritoneum renders this extremely unlikely. Is primary communication of a simultaneous wound of the artery and vein a possible contingency? From a case upon whicl I operated with Cotte for arterio-venous aneurism of the hypogastric (internal iliac) vessels it would seem tha it is. In December 1915 this man was hit by a bullet which traversed the abdomino-pelvic cavity obliquely, running from the left flank to the right trochanteric region. Laparotomy had

been immediately performed, and several intestinal perforations had been sutured. Several months later symptoms of pelvic arterio-venous aneurism made their appearance, and became progressively more marked. Operation revealed an arterio-venous aneurism of the hypogastric vessels. The original laparotomy had revealed no abnormal condition of these vessels, and it is certain that at that time there was no hæmorrhage from the vascular wound.

In spite of exceptional cases of this kind, wounds of the pelvic vessels which are amenable to treatment must be regarded as extremely rare.

I do not know of a single case of operation during the last two years upon wounds of the common or internal iliac arteries. On the other hand, several cases of lesion of the external iliac, as well as of the extra-pelvic branches of the hypogastric, have been observed and treated. The results are briefly as follows :—

The external iliac and its companion vein have been injured by bullets traversing the iliac fossa either obliquely or from front to back, or by spent shell-fragments arrested by contact with the vessels. Tuffier has reported a case of this description to the Société de Chirurgie, which was observed by Letoux. A fragment of a bomb entered at the level of the anterior superior iliac spine. The opening-up of the wound did not reveal the vascular injury, which was manifested fifteen days later by the appearance of a secondary diffuse hæmatoma. The external iliac was ligatured; death followed, however, as the result of secondary hæmorrhage. I saw a case in which a ball which entered the buttock near the ischium and came out a little above Poupart's liga-

ment shattered the lower end of the artery. I was able to open the hæmatoma and effect direct hæmostasis. One of my colleagues recently sent me an account of a wound of the external iliac by a shell-fragment. Ligature was followed by gangrene of the entire limb, necessitating disarticulation at the hip two days later. Soubbotitch has reported two cases to the Société de Chirurgie in which hæmatoma resulted from a wound of the external iliac. Double ligature of the vessel was followed in one case by recovery, in the other by death.

These scanty results do not afford sufficient material for the construction of a clinical history of wounds of the external iliac in general. They do, however, show that, excluding those cases—probably the most numerous—in which injury is immediately followed by formidable internal or external hæmorrhage, there are instances in which the vascular wound gives rise to arterial or arterio-venous hæmatoma.

This hæmatoma appears as a voluminous swelling situated immediately above Poupart's ligament, which raises the anterior abdominal wall and extends upwards beyond the iliac crest towards the lumbar region. In the case of my own, to which I referred above, the tumefaction was enormous; it was almost as large as the head of an adult. The ecchymosis covered the iliac fossa, the buttock, and the entire external surface of the thigh. Arterio-venous hæmatoma is naturally much less voluminous. In certain dry wounds the absence of hæmorrhage is explained by the presence of primary aneurismal varix; three such cases have been observed by Soubbotitch.

It is hardly necessary to point out that all lesions

of the iliac vessels demand immediate surgical intervention. The operative measures comprise temporary occlusion of the commencement of the external or common iliacs, free incision of the hæmatoma, and direct treatment of the vascular wound. I remind my readers that, to expose the root of the external or common iliac a long incision should be made a finger's-breadth above Poupart's ligament and parallel to it, commencing a little outside the external abdominal ring, following the arch of the ligament as far as its centre, then gradually curving upwards until it runs perpendicularly to the ligament. The cellular tissue and the aponeurosis of the external oblique are incised until the internal oblique is reached; the inferior border of the latter is found with the finger, and the muscle is severed transversely and vertically against the finger with the scissors. The transversalis is dealt with in a similar manner. The peritoneum is then gradually separated by means of a finger introduced into the wound, and is retracted upwards. Quite at the beginning of this manipulation the external iliac artery is found, and the separation of the peritoneum is continued along its course until its commencement is reached, where the vessel is either provisionally ligatured or clamped.

The second stage of the operation consists in the free exposure of the vascular wound and the evacuation of the hæmatoma. The third stage comprises direct arrest of hæmorrhage. Statistics taken before the war show that ligature of the external iliac is not a very dangerous undertaking. According to Monod and Vanverts, the proportion of gangrene is 3·8 per cent. Before the war, however, suture of

this vessel was performed six times. Of these, five were lateral sutures and one circular. The method was successful in four cases, unsuccessful in one, and there was one death. I do not know of any case of suture of a recent wound of the external iliac since the war. Except in the case of a small lateral suture, the extensive and comprehensive exposure of the wounded vessel necessitated by the method renders its employment inexpedient in the surgery of war. The occasions for its employment are very rare.

Wounds of the gluteal and sciatic arteries are more frequently observed at field ambulances than wounds of the external iliac. They usually result from shell-wounds, rarely bullet-wounds, of the buttocks. Vast lacerated wounds of the buttocks by large projectiles are very common. I have frequently seen pieces of iron as large as a hen's egg which had ploughed up the muscles and were still embedded in them. On one occasion I saw a shell-fuse which had traversed the buttock and penetrated the iliac fossa into the pelvis, where it had injured the rectum. During its course the spring attached to the fuse had become uncoiled, and when the patient came into my hands 2 inches of it were projecting from the external wound. These extensive injuries are extremely serious, and their gravity is enhanced by the presence of co-existing vascular lesions.

Wounds of the gluteal and sciatic arteries rarely give rise to serious external hæmorrhage. In the vast majority of cases they produce a diffuse hæmatoma, the very diffuseness of which militates against its recognition. The buttock becomes voluminous and tense; there are no other signs of vascular

injury. This symptom alone, however, is a sufficient indication for immediate surgical intervention.

Exposure of the gluteal artery at the upper part of the great sacro-sciatic notch, and of the lower part of the sciatic artery, is effected by means of a large incision, which commences two fingers-breadths below the posterior superior iliac spine, runs upwards and outwards to the level of this spine, and from there runs directly outwards and downwards, following a line joining the posterior superior iliac spine to the trochanter. Having exposed the gluteus maximus, one of its muscular interspaces is penetrated until the loose cellular tissue beneath it is reached. To facilitate the turning back of the inferior flap of the muscle the insertions of the muscular fibres to the outer border of the great sacro-sciatic ligament are divided. The muscle is then turned back, and at the bottom of the wound the pyriformis muscle is seen, at the upper border of which, close to the bony arch, the gluteal artery is situated. The sciatic artery is found at the lower border of the muscle, close to the spine of the ischium.

It is not always easy to place a ligature upon the gluteal above its bifurcation. The artery is closely adherent to the periosteum, and is very difficult to isolate and secure. In many cases it is necessary to abandon ligature and employ a long pair of artery-forceps, which are left on for forty-eight hours. Where the artery is so adherent to the periosteum, or so retracted within the pelvis that it is not possible to get hold of it, should ligature at a distance, namely, ligature of the hypogastric (internal iliac) by way of the abdomen, be resorted to? Before having recourse to this supplementary operation, I think

that it is better to try and free the artery *in situ*, removing where necessary a more or less extensive portion of the bony arch by means of a gouge-forceps. Although it has long been proved that ligature of the hypogastric is free from danger, I advise that every effort be made to ligature the gluteal in the wound before resorting to laparotomy upon a patient whose general condition is usually very feeble.

PELVIC ANEURISM

Pelvic aneurism due to war-wounds is extremely rare.

Before the war a few isolated cases of arterial *aneurism of the common iliac* had been observed. In the last two years, however, I do not think that a single case of aneurism of the common or internal iliac has come under operation. The first and only case of operation for a pelvic aneurism is one which I saw with Cotte and reported to the Société de Chirurgie. This was an arterio-venous aneurism of the hypogastric (internal iliac) vessels following an abdomino-pelvic wound. When the patient came under observation we found a loud thrill, which was particularly clear in the neighbourhood of a distended cicatrix left by laparotomy. The patient presented all the clinical signs of a large arterio-venous aneurism. The symptoms of marked circulatory derangement of the left lower limb and the intense cardiac symptoms —palpitation, oppression, pain—were clear indications for surgical treatment.

Laparotomy revealed the existence of a tumour the size of the fist, filling the entire space of the true pelvis, and displacing the pelvic colon upwards and

towards the right. It was adherent in front to the bladder, at the back to the hollow of the sacrum, and on the left to the external and internal iliac vessels close to the common iliac. The tumour was very markedly pulsatile. After successive isolation and temporary command of the common, external, and internal iliacs I found that the aneurism was in communication with the two last-named vessels. This finding was confirmed by ligature of the hypogastric, and I then undertook the dissection of the sac. After several attempts I was compelled to abandon its complete extirpation and content myself with incision. I was then able to secure permanent arrest of hæmorrhage by means of a forceps left *in situ* on the peripheral end of the hypogastric, which I had found it impossible to tie. The remainder of the sac was marsupialised, and the abdomen closed without drainage. The patient died in the evening. The post-mortem findings did not reveal the cause of death. The tumour was an enormous varicose aneurism; the sac was derived from the wall of the vein only; the artery was slightly dilated, and opened into the sac by an orifice large enough to admit the tip of the index finger (fig. 60). This is the only known case of operation for pelvic aneurism.

Aneurism of the external iliac and of the gluteal and sciatic vessels is less rare.

Before the war twenty-four cases were collected by Monod and Vanverts. In six cases only was extirpation attempted; of these, three recovered and three died. It is hardly necessary to point out that its situation, its anatomical associations, and the nature of the adhesions which it forms with the

peritoneum, combine to render extirpation of *aneurism of the external iliac* a matter of extreme difficulty. The sub-peritoneal method does not, after all, effect complete exposure; it yields only a restricted operative field, within the limits of which manipulation is very difficult. It is not surprising under

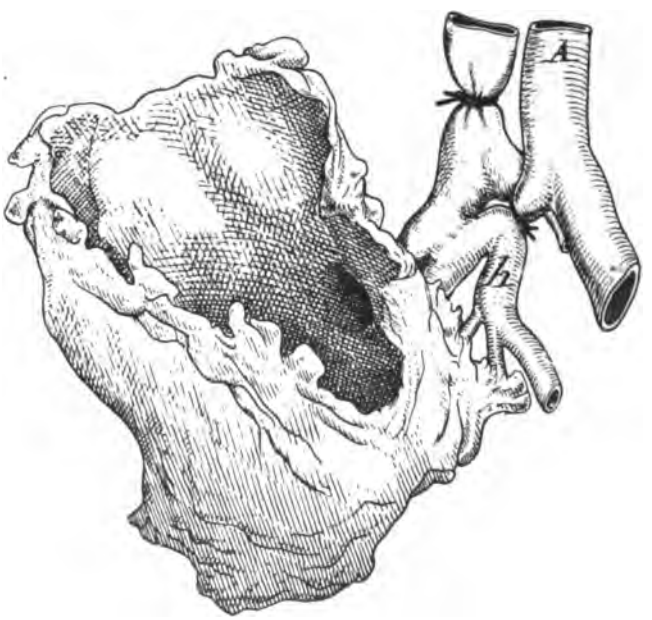

FIG. 60.—Arterio-venous aneurism of the hypogastric (internal iliac) vessels. (Sencert and Cotte.)

these circumstances that aneurism of this class has most frequently been treated by indirect methods, either ligature above or ligature above and below. Ligature above has been performed on the aorta, the common iliac, and the external iliac at its point of origin. Three cases of ligature of the aorta resulted in three deaths, four of ligature of the common iliac in two deaths (Monod and Vanverts); of seven

recent cases of ligature of the external iliac none ended in death. Gangrene of the limb is exceptional.

It is obvious, then, that it is not always possible to decide in advance upon the method of treatment for an aneurism of the external iliac. The ideal method here, as elsewhere, is by extirpation, but the difficulty of the operation is frequently so great as to constitute a contra-indication. The best method is first to secure the artery above; an attempt is then made to ascertain the anatomical conditions of the tumour, its relationship to neighbouring organs, and the nature of its adhesions. If it is readily extirpable, it should be removed; if not, treatment should be confined to ligature above.

Gluteal aneurism may be either exclusively gluteal, or both gluteal and pelvic. It is unfortunately very difficult to ascertain the exact topography of these tumours in advance, and, in the majority of cases, the conditions are revealed only by operation.

Extirpation, the method of perfection, is rendered infinitely more difficult and more complex by the prolongation of the gluteal sac into the pelvis. In such a case extirpation must be abandoned, and ligature at a distance by Hunter's method adopted. Monod and Vanverts have collected twenty-four cases of extirpation of gluteal aneurism, with a mortality of 20·7 per cent. This high mortality is due to the extreme danger of operation in cases where the aneurism has spread into the pelvis. The chief difficulty is to assure efficient hæmostasis, and in several cases of persistent hæmorrhage from the gluteal it has been necessary to resort to ligature of the hypogastric.

Ligature of the internal iliac, usually a temporary expedient in gluteal aneurism, is in certain cases the method of choice. The benignancy of this ligature renders it an eminently suitable preliminary to extirpation, and, where it is adopted, extirpation is easier and much more sure.

CHAPTER VIII

WOUNDS OF THE FEMORAL VESSELS

DIFFUSE FEMORAL HÆMATOMA

Owing to the great length and the superficial position of the femoral vessels they are frequently wounded. The majority of wounds are situated in the neighbourhood of Scarpa's triangle, for here the vessels approach the surface of the limb. Next in frequency are lesions of the lower end, where the vessels are firmly fixed in the popliteal space and are immovable. It is said that the middle part so frequently escapes injury owing to its mobility.

When brought into the field ambulance, in exceptional cases these injuries appear as large lacerated wounds filled with clots, beneath which the hæmorrhage is temporarily arrested. Such are certain wounds at the root of the thigh complicated by considerable loss of the tissues of the hip or buttock, and certain comminuted fractures of the upper third of the femur. I remember one case in which the femur was shattered by a bullet which entered at the gluteal fold and emerged in front at the apex of Scarpa's triangle; the artery was torn by a splinter from the bone. At the operation it was still fixed between the two segments of the vessel. Occasionally the limb

is literally smashed up, or almost completely torn off at the middle of the thigh, with rupture of the vessels. It is superfluous to point out that such injuries are of extreme gravity. The traumatic shock is intense, and the majority of cases succumb shortly after their arrival. Nevertheless I have known a few recover.

In the vast majority of cases, however, the wounds are perforating in character, and may be caused by either bullets or shell-fragments. The vascular wound is commonly accompanied by a diffuse hæmatoma, and the amount of blood effused is sometimes enormous. This is explained by the superficial position of the artery in its upper third, and by the nature of the cellular tissue of the thigh, which is capable of considerable distension. An enormous hæmatoma is formed, which raises the skin of the front of the thigh from Poupart's ligament to the knee. The swelling is not always confined to the anterior aspect; not infrequently it spreads to the antero-internal region, and is infiltrated between the adductors. This is due to the fact that either the course of the bullet naturally gives rise to effusion of blood beneath the quadriceps, or (and this is more frequent) that the deep as well as the superficial femoral artery is injured (fig. 61). It may happen that the swelling is bilocular, one sac being formed from the lesion of the superficial, the other from the lesion of the deep femoral. The hæmatoma may even invade the posterior portion of the thigh by following the course either of the projectile or of a perforating artery. A point to which it is expedient to draw attention is the possibility of the appearance of a voluminous diffuse hæmatoma of the thigh, due not to injury

FIG. 61.—Arterial topography of the thigh. Anterior view. (Broca.)

FIG. 62.—Arterial topography of the thigh. Posterior view. (Broca.)

of a main artery but to injury of one of its branches. In front it may proceed from the circumflex, the artery to the quadriceps, or a perforating artery at its point of origin. Behind it may come from one of the perforating arteries (fig. 62). A wound of one of these vessels alone may give rise to a very considerable hæmatoma, which may to all appearance come from the femoral itself. The treatment of this type of lesion is sometimes a difficult matter; we shall return to the subject later.

The femoral vein is frequently injured with the artery. The resulting arterio-venous hæmatoma is generally less voluminous than one of arterial origin alone. Simple primary direct connection between artery and vein is rare; Makins has, however, observed five cases.

The indications for the treatment of lesions of the femoral vessels are similar to those of vascular wounds in general. At the first aid-post, or even in the trenches, the medical officer who is called upon to deal with severe hæmorrhage from a large thigh wound should effect temporary arrest of hæmorrhage as rapidly as possible. It is essential that he should not allow himself to become confused, and that he should distinguish, above all, between hæmorrhage of arterial and venous origin. It has frequently happened, even during this war, that a wounded femoral vein has continued to bleed after the ill-judged application of a tourniquet above the wound, when a simple pad would have controlled the hæmorrhage. When, however, it is certain that the hæmorrhage is of arterial origin, a tourniquet should, if possible, be applied above the wound. If the wound is situated in Scarpa's triangle, the tourniquet is

useless, and the hæmorrhage must be controlled by digital pressure in the wound (fig. 68). If this measure is unsuccessful, the cutaneous wound should be closed by the application of one or more forceps. A special label should be attached to the patient calling the attention of the surgeon to the case, which should be at once dispatched to a field ambulance with directions to keep the patient as still as possible during transport. In an earlier chapter I described a case in which hæmorrhage from the femoral had been arrested by means of a pad, but the patient insisted upon getting out of the ambulance unaided; hæmorrhage recommenced, and he died in a few seconds.

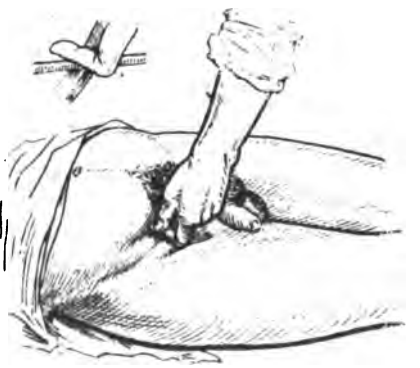

FIG. 63.—Digital compression of the femoral artery. (After Farabeuf.)

At the field ambulance the surgeon finds either a large wound filled with clots or, more frequently, a penetrating wound and a diffuse hæmatoma. In the case of the first, immediate operation with the object of controlling the hæmorrhage is indicated. In the case of the second, immediate operation is also indicated with the object of evacuating the hæmatoma and preventing its recurrence. The necessity for immediate intervention in diffuse hæmatoma of the thigh cannot be too strongly emphasised. The size of the hæmatoma exposes the limb to the danger of rapid gangrene. In the case of a shell-wound the imminence of grave infection and of gas

gangrene is so menacing, that operation should not be postponed for even a few hours.

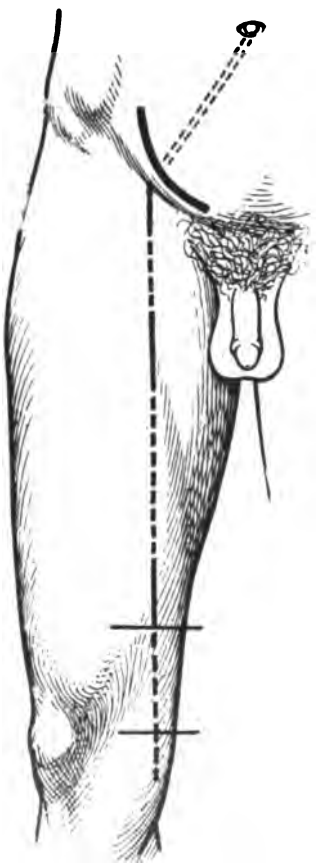

FIG. 64.—Line of the femoral artery. (Broca.)

The first stage of operation consists in temporary hæmostasis by securing temporarily the arterial trunk above the wound. If the hæmatoma is in Scarpa's triangle, the temporary ligature is placed on the external iliac. The method has already been described. In the case of a hæmatoma of the middle or lower part of the thigh, the femoral is secured at the base of Scarpa's triangle. The method is as follows: The skin over Scarpa's triangle is incised for 2 inches along the line of the femoral, that is to say, along a line from the centre of the fold of the groin to the back part of the internal condyle (fig. 64). The incision should commence half an inch above the fold of the groin.

The white fibres of Poupart's ligament should be well exposed. Then the fascia lata should be carefully divided, preferably upon a grooved director introduced through a hole in the cribriform fascia. The edges of the incised aponeurosis are retracted, exposing the artery with the vein close to its inner side. The portion of the artery immediately

beneath Poupart's ligament should be cleared and the thread passed. By placing the temporary ligature in this position the circulation in both the superficial and deep femoral is arrested.

When temporary control of hæmorrhage has thus been assured the hæmatoma is incised. The incision should be a long one, and follows the femoral line. The sartorius is easily recognised; should it hinder exposure of the whole extent of the blood-filled cavity, it should be divided transversely. The cavity should be well mapped out and the exact position of the vascular wounds ascertained. The injury may be in the femoral artery, femoral vein, or in both; there may be multiple wounds of the artery and vein and their branches. The exposure of these wounds frequently demands long and careful examination, the difficulties of which are well known to surgeons at the front.

In the case of a wound of the femoral artery or vein, or of both, what is the method of procedure?

Ligature of the artery, even before the war, had lost much of its bad reputation. In 1909 it was generally admitted that gangrene followed in 20 per cent. of cases. Yet in 1910, Monod and Vanverts observed only a single case of gangrene among twenty-one cases of ligature of the femoral artery for diffuse hæmatoma. In five cases the ligature was on the common femoral, and in all five cases recovery was complete. Simultaneous ligature of the artery and vein preserved its evil reputation somewhat longer. Before the war gangrene was said to follow in 50 per cent. of cases.

I am of the opinion that ligature of the femoral artery is not as dangerous to the vitality of the limb

as it is commonly believed to be. The frequency of gangrene depends very much upon the clinical conditions under which ligature is performed, and varies according to whether the lesion is a large and lacerated wound or a voluminous hæmatoma. In the case of the first, gangrene is extremely rare. I have ligatured the femoral artery eleven times in recent injury without large hæmatoma; in three of these cases the common femoral was tied; in seven the superficial femoral, with, in two cases, concomitant lesion of the deep femoral. In no case did gangrene follow. In at least two cases out of three the vein was also injured. On the other hand, I have operated nine times upon large diffuse hæmatoma of the thigh. In one case gangrene of the entire limb followed, a gangrene which was both mechanical and septic, and which necessitated amputation high up the thigh. Contrary to expectation the patient recovered. In one case there was gangrene of the leg, and in two cases circumscribed necrotic patches appeared on the toes, sole and dorsum of the foot. In addition to these personal observations, I have found scattered through the literature of war-surgery about twenty cases of ligature of the femoral vessels for hæmatoma of the thigh. Monod and Baumgartner, Baudet, Lapeyre, Le Moniet, have not observed gangrene. Out of three cases observed by Soubeyran, one case of gangrene, chiefly of septic origin, occurred. Sébileau alone has had a series of unfortunate experiences. Gangrene followed operation for diffuse aneurism of the thigh in each of his four cases. It should be remembered, however, that these operations were performed at the beginning of the war. Makins observed gangrene in only five out of thirty-five

cases, and in two of these gangrene was present before operation. It is evident then that although ligature of the femoral artery does not entirely deserve its unfavourable reputation, it is nevertheless associated with a certain amount of risk.

Suture of the femoral artery was performed on several occasions before the war. Monod and Vanverts describe thirty-two cases, twenty-six of lateral and six of circular suture. In no case was operation followed by circulatory disturbance in the limb. Before the outbreak of war I performed lateral suture of the femoral artery four times. In one case there was infection and secondary hæmorrhage, necessitating ligature in the wound; the patient recovered. In war practice, on the other hand, I have not once had occasion to suture the femoral artery, the anatomical conditions in every case which has come into my hands constituting a contra-indication. Pauchet performed lateral suture of the femoral in the case of a small wound the size of a lentil. But of twenty-five cases of arterial hæmatoma operated upon by Soubbotitch, ligature was performed twenty times, with three gangrenes and one death; suture five times, three being lateral, with two successes and one failure, and two circular, with two recoveries.

These results are encouraging. Where, in diffuse hæmatoma of the femoral, there is reason to anticipate gangrene—that is to say, if the limb is pale and cold, if the lower end of the artery does not bleed, if the lower end of the vein does not fill when closed by the forceps—in such cases lateral suture and, where necessary, circular suture should be attempted. Where suture is impossible, recourse must be had to ligature.

FEMORAL ANEURISM

Femoral aneurism consequent upon wounds of war is extremely rare. I have been able to discover only three cases of arterial aneurism, though arterio-venous aneurism is somewhat more frequent.

An arterial aneurism observed by Le Jemtel appeared as a small tumour situated in the fold of the groin. In the two cases described by Hotz the tumour was more voluminous; it was as large as the fist, and was situated in one case in Scarpa's triangle, in the other, in the middle of the thigh. The aneurisms were regular in shape, rounded, smooth, and of varying consistency. They presented all the stethoscopic characteristics of arterial aneurism.

The method of treatment *par excellence* is by extirpation of the sac. Before the war Monod and Vanverts had collected thirty-six cases of arterial aneurism of the superficial femoral, twenty-seven of which were treated by extirpation, with twenty-four recoveries, one gangrene, and two deaths. But within the last two years operations of this type have become very rare. In Le Jemtel's case operation included the ligature of numerous vessels, and gangrene, terminating in death, ensued. In one of his two cases Hotz attempted repair of the femoral artery by implanting a portion of vein 2½ inches in length obtained from the forearm. In the second case he performed circular suture of the artery. Both cases made an uncomplicated recovery.

Taking into consideration the possibility of wounds of more vessels than one, both in the neighbourhood of Scarpa's triangle and all along the line of the femoral artery, extirpation of a femoral aneurism may

well be a complex operation, and the preliminary measures to control the hæmorrhage particularly long and difficult. Owing to the infrequency of gangrene after ligature of the femoral, the best method of dealing with the loss of substance consequent upon extirpation of the sac is by double ligature. Circular suture must be regarded as an exceptional measure, and venous transplantation even more so.

In the case of the femoral as of other great vessels, arterio-venous aneurism is more frequent in war-surgery than arterial aneurism. I have seen the histories of fourteen cases in the French literature of the subject published since the war. Soubbotitch has described twenty-one personal cases, and Makins eleven. More than half of the cases which have come under operation have been those of aneurismal varix in every variety of position upon the femoral vessels. The varicose aneurisms observed have varied from the size of a plover's egg (Walther) to an enormous tumour extending from Poupart's ligament to Hunter's canal. The characteristic symptoms of arterio-venous aneurism were very marked in all the cases.

The best method of treatment is undoubtedly by extirpation of the anastomotic arterio-venous segment. In the case of aneurismal varix, it has never yet been possible to ligature the small canal between the two vessels. Soubbotitch has twice performed lateral suture of the arterial wound with ligature of the vein, and once lateral suture of both artery and vein. In the majority of cases aneurismal varix has been treated either by quadruple ligature or by extirpation of the anastomotic segment. This is due to the fact that, owing to the very extensive adhesions by which the vessels are united, it is frequently very difficult

to discover the precise neighbourhood of the communication. In one case Makins was unable to find the track, and was compelled to operate again later. Moreover, branches almost invariably start from the point of anastomosis or its immediate vicinity. These conditions demand a more complex operation than simple removal of the communication; extirpation of the anastomotic vascular segment or, failing that, quadruple ligature is indicated. The same indications apply to varicose aneurism. Extirpation has been successfully performed by Walther, Broca, Mauclaire, Pozzi, Auvray, Bousquet, and probably by others. Bérard, Duval, Soubeyran, Quénu, Arnaud, have all employed quadruple ligature.

The venous and arterial wounds left by extirpation of the aneurismal sac have been treated variously by either ligature or suture. Ligature has been employed in the greater number of cases. Soubbotitch has, however, performed circular suture of the artery with lateral suture of the vein. In one case circular suture was followed by death. Hotz resected ½ inch of the femoral artery and replaced the resected portion by a segment 2 inches in length obtained from the femoral vein. The pedal pulse immediately reappeared. Makins has once successfully performed lateral suture of the arterial wound after extirpation of the intervascular sac.

Arterial reconstruction of this kind is extremely tempting, but the indications for its employment, especially in the class of case under consideration, are reduced by the extreme benignancy of double ligature of the femoral vessels. Among the cases mentioned in the preceding paragraph, there was no instance of gangrene after extirpation of the

aneurism and ligature of the vessels. It must not be imagined, however, that gangrene is not a possible contingency. Are we to assume, moreover, that recovery is as satisfactory after permanent occlusion of the femoral vessels as after their repair? Mauclaire as well as Bousquet have given it as their opinion that after occlusion of the vessels œdema and a certain degree of loss of power persist. It is true that the circulation may suffice to stave off gangrene, and may yet be insufficient to assure the perfect function of the limb. In such a case the subject, though quite comfortable in repose, may yet be unable to walk half a mile; movement induces pain, œdema, and intermittent claudication, which testify to insufficiency of the distal circulation. Soldiers who have been operated upon in this manner are unfitted for active service. I think that this is a factor which should be taken into careful consideration in cases where the choice lies between ligature and suture. My own view is that, when operation is undertaken at the base, with every surgical facility, and under conditions approximating to those of times of peace, vascular suture is practicable in a far larger proportion of cases than was formerly believed to be possible.

When extirpation of the aneurism is impracticable, recourse must be had to multiple ligature. In some instances it is necessary to tie four, six, or eight vessels. In cases such as these operation becomes a matter of extreme gravity and difficulty. A patient of Duval's died, and another recovered only after disarticulation at the knee. When, owing to the multiplicity of the vascular lesions and fusion with the neighbouring tissues, extirpation of the aneurism is impossible, the case is one of extreme gravity.

CHAPTER IX

WOUNDS OF THE POPLITEAL VESSELS

DIFFUSE HÆMATOMA

WOUNDS of the popliteal vessels are seen in association with lateral or posterior wounds of the knee, or with penetrating bullet-wounds of the knee joint. They are usually accompanied by considerable damage to the limb, but are occasionally seen in connection with simple wounds of the soft parts.

In large wounds of the popliteal space with injury to the vessels spontaneous arrest of hæmorrhage is rare. The rigid walls of the popliteal space keep the wound wide open, and the conditions are not favourable to spontaneous hæmostasis. Occasionally, however, the hæmorrhage is temporarily arrested by involuntary flexion of the leg upon the thigh, and the patient arrives in this condition at the ambulance. In the majority of cases the external wound is small, and a diffuse hæmatoma forms and rapidly acquires characteristics of considerable gravity. Owing to the rigidity of the structures forming the popliteal space the collateral vessels rapidly become compressed, and a hæmatoma of apparently small dimensions may soon produce coldness of the limb followed by gangrene. Makins states that out of eight cases of

injury to the popliteal vessels, in seven gangrene followed very rapidly before intervention was possible. The hæmatoma is confined to the popliteal space, its diffusion being hindered by the fibrous bands which limit the region above and below. Occasionally it invades the knee joint, producing a variety of pulsatile hæmarthrosis. In exceptional cases the hæmatoma is very small, and may pass unperceived.

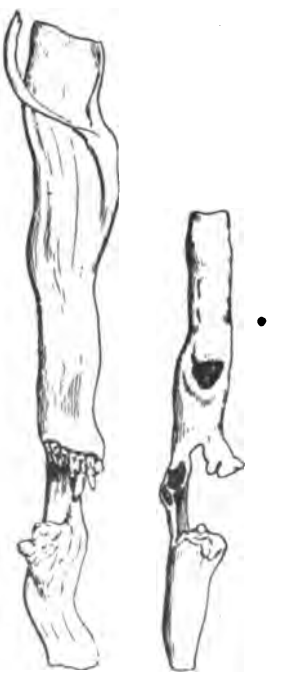

FIG. 65.—Wound of the popliteal vein by a rifle-bullet. Partial section of the internal popliteal nerve. Death was almost instantaneous. (Latarjet's case. Val-de-Grâce Museum.)

Wounds of the popliteal vessels are frequently accompanied by lesion of the sciatic nerve (fig. 65). From its position in immediate contact with the vessel the internal popliteal nerve is more exposed to injury than the external branch. Clinical experience shows, however, that paralysis of the internal popliteal is practically never observed alone, but is almost invariably accompanied by paralysis of the external popliteal.

The extreme gravity of the symptoms of compression provoked by the hæmatoma is an urgent indication for immediate surgical intervention.

The first stage of operation consists in securing temporary hæmostasis by means of Esmarch's bandage

applied at the root of the thigh, or by temporary occlusion of the artery above the tumour, either in Hunter's canal or at the upper angle of the popliteal space.

To expose the femoral in Hunter's canal, the limb is extended and rotated outwards, and an incision 8½ inches in length is made along the femoral line down to four fingers-breadths above the internal condyle. After the deep fascia has been incised, the outer border of the sartorius is defined and pulled inwards and downwards. The thigh is now somewhat abducted, and rotated outwards with the leg flexed; this exposes the anterior wall of Hunter's canal, from the lower part of which the internal saphenous nerve emerges. A grooved director is introduced into the canal along the orifice of exit of the nerve, and is insinuated upwards by pressing it against the outer aspect of the adductor tendon; the anterior wall of the canal is then incised on the director, and the femoral vessels are exposed between the two edges of the incision.

To tie the artery in the upper part of the popliteal space a longitudinal incision 4 inches long is made along the median line of the popliteal space, the lower extremity of which does not extend beyond its centre. The skin, cellular tissue, and deep fascia are directly incised. Beneath the outer edge of the incision the external popliteal nerve is seen, and this is freed and retracted outwards. By separating the loose cellular tissue deeper down in the popliteal space, the vessels are exposed in the median plane close to the bone. The vein is first seen; the artery lies on its inner aspect and quite close to it.

Temporary hæmostasis having been assured, the

hæmatoma is freely incised and the vascular lesion exposed. If it is a wound of the vein only (and these are frequent) the vessel is tied. The operation is simple, easy, and entirely free from risk. On three or four occasions I have tied the popliteal vein without untoward consequences. Should there be a wound of the artery or of the artery and vein, should ligature be performed, or should an attempt be made to repair the vessels by suture?

Ligature of the popliteal artery has long been regarded as a very serious operation. Statistics show that before the war gangrene followed in a proportion of cases, which varies with different authors from 33 to 54 per cent. Ligature is particularly dangerous when placed upon the lower part of the vessel in the neighbourhood of the bifurcation.

The gravity of ligature of the popliteal artery depends, firstly, upon the small number of collateral branches; and, secondly, upon the fact that those that exist do not readily assume the functions of the main trunk.

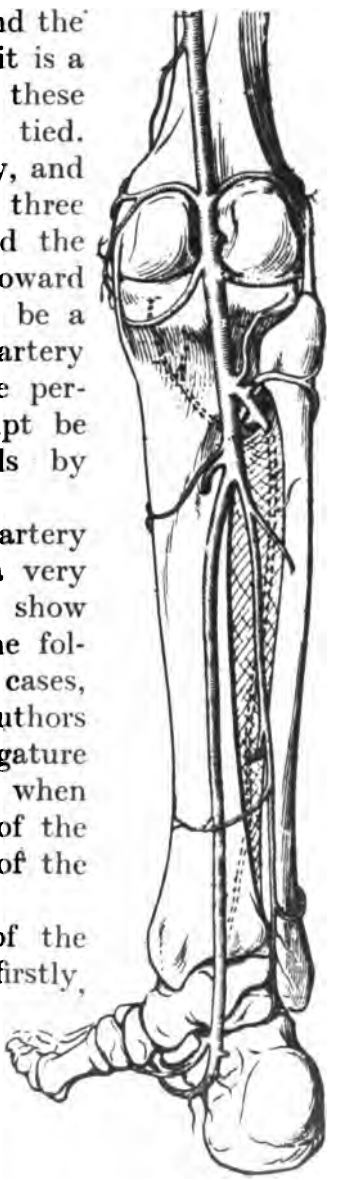

FIG. 66.—Arterial topography of the leg and foot. (Broca.)

Although they are not

very numerous, there are a certain number of branches of the popliteal which anastomose lower down with the terminal branches, the posterior and anterior tibial. These are the anterior and posterior tibial recurrents and the peroneal recurrent (fig. 66). All these vessels, however, arise quite close together near the lower end of the popliteal, and a ligature which obliterates the posterior and anterior tibial also suppresses these branches. Hence the danger of ligature of the lower end of the artery.

Moreover, these branches do not readily assume the functions of the main artery. It is a general law in human anatomy that tissues and organs are vascularised in accordance with their functional activity. The muscles and viscera are supplied by large arterial trunks, the tendons and aponeuroses by very small vessels. Further, in view of the very considerable variations in volume presented by the muscles when active and when in repose, the arteries by which they are supplied should be capable of responding to a varying demand. In the parts of the body where the arteries are called upon to feed groups of powerful muscles, they are furnished with numerous large branches. In the regions where they supply tendons or fibrous capsules, the vessels are few in number and small in size. The latter condition obtains in the case of the knee. Between the muscles of the thigh, which are supplied by the femoral and its branches, and the muscles of the leg, which are supplied by the tibial arteries, there is an anatomical region composed solely of tendons and a fibrous capsule, all of which are very slightly vascular. Hence the poverty in numbers and the attenuation in calibre

of these branches of the popliteal. Should the popliteal trunk be obliterated, its slender branches are frequently unable to take its place. The results are not always expressed by gangrene; the impaired circulation, though sufficient to preserve life in the leg and foot, is yet insufficient adequately to maintain their functions. The poverty of the circulation is enhanced by compression of the vessels by the hæmatoma, and the vitality of the limb is further compromised by lesion of the nervous trunks. Under these circumstances it would not be surprising if gangrene, though not frequent, were yet more common than we have hitherto thought it.

I have ligatured the popliteal six times in cases of lacerated wound or small hæmatoma, and have once observed gangrene of the leg and foot. Out of five ligatures in cases of large hæmatoma, I have twice observed partial gangrene of the limb. Makins has observed gangrene eight times out of nine in cases of large hæmatoma, in seven cases before operation, and in one after. Soubbotitch had two cases of gangrene out of seven ligatures for hæmatoma. Soubeyran, Maisonnet, Oudard have each observed a case of gangrene. On the other hand, gangrene did not occur in cases described by Picqué, Frédet, J.-L. Faure, Le Moniet.

These results confirm the views expressed in the preceding paragraph. Ligature of the lower end of the popliteal artery is an operation which, though it does not deserve the bad reputation formerly attaching to it, is yet attended by a certain degree of danger, seeing that gangrene follows in 25 per cent. of cases. Moreover, and this point cannot be too strongly emphasised, absence of gangrene does not imply a

perfect circulation, for the functional activity of the limb may be very much impaired.

Here also ligature has sometimes been replaced by suture. In one case of diffuse popliteal hæmatoma Pauchet performed lateral suture of an arterial wound the size of a lentil. Soubbotitch performed lateral suture of the popliteal artery three times, with one failure, one death, and one result unknown. Lenormant describes a case of lateral suture of the popliteal artery in which gangrene followed, necessitating amputation. The clinical material provided by these histories is meagre indeed—a very small number of cases of suture attended by very mediocre results. Here, as elsewhere, the indications for primary vascular suture are extremely rare.

POPLITEAL ANEURISM

In times of peace a popliteal aneurism is one of the forms of aneurism which are most frequently met with. Popliteal aneurism following on a war-wound is, on the contrary, extremely rare.

Popliteal arterial aneurism appears as a tumour of varying size, moulded into the popliteal space and bulging outwards and upwards. The bands of fascia by which the space is bounded usually prevent the extension of the tumour into the thigh or calf. Confined as it is in a circumscribed area, the tumour rapidly produces marked symptoms of compression. There is compression of the popliteal and external saphena veins, giving rise to œdema and cyanosis of the limb; and compression of the branches of the sciatic nerve, inducing sensory and motor disturbances as well as trophic derangements.

The best method of treatment is undoubtedly by extirpation of the sac. Monod and Vanverts collected ninety such cases, with five gangrenes and one death. Within the last two years, however, the operation has become exceedingly rare. Quénu undertook the extirpation of a popliteal arterial aneurism, but was compelled to abandon total excision of the sac owing to its adhesion to the surrounding structures. Even when incomplete, however, here as elsewhere extirpation is superior to simple proximal ligature. Since the war, Matas' endo-aneurismorraphy has been successfully performed by Soubbotitch once. Is the method preferable to extirpation? The clinical material at our disposal is too scanty to furnish a categorical answer to this question.

Arterio-venous aneurism is more frequent than arterial aneurism. In rare cases it assumes the form of a simple union between artery and vein. Makins has observed two such cases out of eight, and one case has been observed in France by Pauchet. In the majority of instances there is an intermediate sac. It is important to note the frequency in these cases of nervous troubles (pain, neuritis).

The ideal treatment of popliteal arterio-venous aneurism is by extirpation of the anastomotic segment, a method which has been frequently employed during the last two years. The deep-seated position of the vessels, their adhesion to the back of the joint, and the association of the sac with the sciatic nerves, all combine to render this operation a delicate one. It has been successfully carried out by Auvray, Rocher, Estor, Le Moniet, Cauchois, Duval, Soubbotitch, and others.

After excision of the sac the double vascular wound

may be treated by either ligature or suture. In one case Pauchet was able to separate the two vessels and to perform lateral suture of each wound. Soubbotitch performed lateral suture of the artery with ligature of the vein; the patient recovered. In another case he sutured both artery and vein; gangrene followed as the result of embolism, and the patient died. Hotz has twice implanted a venous segment in the arterial gap after wide resection on both artery and vein. In both cases recovery followed With these few exceptions ligature is the method employed, and no case of complication by gangrene has been reported.

CHAPTER X

WOUNDS OF THE VESSELS OF THE LEG AND FOOT

WOUNDS of the vessels of the leg and foot are very common; *wounds of the posterior tibial vessels*, which constitute so grave a complication of injuries of the calf, are particularly so. They are commonly observed in cases of comminuted fracture of the tibia and fibula. The wound is widely gaping and filled with clots. The wound in the vessel, temporarily closed by a clot, by shreds of clothing, or by a splinter, is disclosed only after minute cleansing of the damaged area.

In the majority of instances wounds of vessels of the leg are complications of small penetrating shell-wounds of the calf. The leg is distended from the knee to the ankle by a diffuse swelling, and the patient complains of severe continuous pain. These symptoms all point to a diffuse hæmatoma of the calf. Not infrequently auscultation reveals a murmur over the back of the leg. On the other hand, in opening up a wound of the calf it is by no means exceptional to discover fortuitously a wound of the posterior tibial, the presence of which was unsuspected. This is an experience which must have befallen all

surgeons who have operated at the front. The arterial wound being blocked by the projectile or by a fragment of clothing, there is no trace of hæmatoma. Careful excision of the wound is the sole means of discovering and treating the arterial injury.

Diffuse hæmatoma of the calf is a condition of considerable gravity. Deeply situated as they are beneath the soleus, and confined between it and the posterior surface of the leg bones, the posterior tibial and peroneal arteries give rise to effusions of blood which infiltrate the entire length of the leg along the interosseous membrane, and which displace the muscles and compress the nerves in its vicinity. In such a case the vitality of all the muscles of the calf is rapidly interfered with, and should anaerobic organism have been conveyed by the projectile to the deeper parts of the wound, gangrene, both ischæmic and septic, is practically inevitable.

Wounds of the anterior tibial are less frequent. The vessel is well protected by the tibia, and these wounds are observed only in association with more or less extensive shattering of the tibia.

In the case of diffuse hæmatoma of the calf, the wound should be well opened up and the bleeding vessel exposed. Hæmorrhage may be controlled by Esmarch's bandage; it is, however, nearly always superfluous.

To reach the posterior tibial or the tibio-peroneal trunk the leg is placed in semi-flexion and semi-abduction, and is somewhat rotated outwards, with the calf unsupported. An incision 4 inches long is made from the level of the anterior tubercle of the tibia down along a line a thumb's-breadth behind the inner border of the tibia (fig. 67). The

integument, cellular tissue, and deep fascia are divided, and the inner border of the inner head of the gastrocnemius is exposed. The muscle is pulled down until 2 inches of the tibia are exposed. In the space thus created the soleus is incised along the entire length of the surgical wound, about 1½ inches internal to the tibia. The incision is deepened until the intra-muscular aponeurosis is reached. This is split; after cutting and retracting some of the deep muscular fibres of the soleus, the

FIG. 67.—Incision for ligature of the posterior tibial in its upper third. (Broca.)

cellular plane in which the vessels are situated is reached. The nerve is first exposed, and then the artery.

Having exposed the vascular wound, the vessel is tied above and below it. It goes without saying that arterial suture is here quite superfluous.

Diffuse hæmatoma of the antero-external region of the leg due to *injury of the anterior tibial* is as rare as diffuse hæmatoma of the calf is frequent. I have, however, seen two or three such cases. The hæmatoma developed in both the antero-external and posterior regions of the leg as the result of a large perforation of the interosseous membrane by the projectile. In such a case it is extremely difficult

to diagnose the wounded vessel in advance. It will be remembered that the anterior tibial line starts from the ante-peroneal hollow and runs to the middle of the instep (fig. 68). Deeply situated as it is, especially in its upper half, the artery is sometimes very difficult to expose. Incision should follow the line just quoted, beginning three fingers-breadths below the level of the knee joint. The fascia is divided, and the inter-muscular septum between the tibialis anticus on the inside and the extensor longus

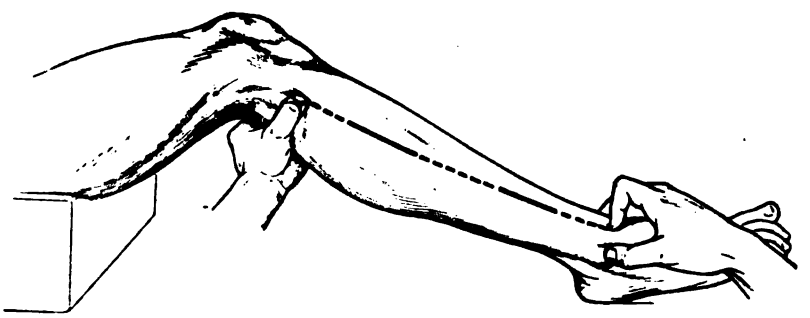

FIG. 68.—Incision along the line of the anterior tibial. (Broca.)

digitorum pedis on the outside is found. This interspace is not easy to find; it should be remembered that it is curvilinear in form, and that the director should be first passed backwards, then horizontally, and afterwards forwards. The artery is at the bottom of the inter-muscular septum close to the interosseous membrane.

Arterial and arterio-venous aneurisms of the leg and foot possess little surgical interest. During the last two years some twenty arterio-venous aneurisms of these regions have come under operation. In all cases extirpation has been attempted. Where complete extirpation was impossible, recourse has some-

times been had to multiple ligature. In no case has either method been followed by circulatory disturbances of the foot and toes.

. . . . . .

This concludes this short study of wounds of the individual vessels. I hope that the young ambulance surgeon will find in it what it has been my endeavour to convey, namely, a clear idea of what should be done in each class of case, and a brief account of the best method of doing it. My own observations during two years of war-service are supplemented by such of the experiences of others as I have been able to find in the home and foreign publications which have come into my hands. If I have omitted to mention observations which would have proved instructive, I crave the pardon of their authors.

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SECTION II

WOUNDS OF THE ABDOMEN

CHAPTER I

THE FACTS AND TEACHINGS OF PEACE-TIME

It is hardly more than twenty years since exploratory laparotomy became so consistently beneficial that one could consider its risks negligible.

And it is hardly more than twenty years since an understanding was come to amongst all, or nearly all, surgeons as to the treatment of abdominal wounds; the question, in fact, was not of simply admitting that an undoubted penetrating wound indicated laparotomy, but it was a complete agreement that even the possibility of penetration justified direct interference by the opening of the abdominal cavity.

. . . . . .

As far back as 1881, under the influence of Marion Sims, American surgeons had been the first to practise and advocate systematic intervention in gunshot wounds of the abdomen; the results—by no means brilliant—produced by laparotomy, still in its infancy, were not greatly calculated to increase the number of its partisans. It is not enough to enunciate opinions vigorously; they must be confirmed by facts. And if it is true that the "French Party," as Kukula writes (1899), remained abstentionist, it could justify itself against the "German and American Party," who were interventionist.

It must be recognised, however, that in 1899 Terrier, whom we are not astonished to find championing a new idea, affirmed the necessity of laparotomy not only in intestinal perforations, but in the case of any

viscera whatever. "I should consider it a paradox," he said, "to maintain that it is not better to sew up a wound (of the stomach) than to leave it to itself. Intervention is therefore imperative, and as speedily as possible." Chauvel, Quénu, and Championnière ranged themselves on his side.

But it was only in January 1895, at the meeting of the Chirurgical Society of Paris, that the doctrine of systematic laparotomy was proclaimed in all its fulness. It was delivered in a speech by Chaput, concerning a case reported by Rochard, and the very animated discussion that followed has become classic.

Called to a woman who had been wounded in the cæcal region and in the epigastrium by two triangular sword-cuts, Rochard operated at once, four hours after the accident. A sub-umbilical incision enabled him to locate and close two perforations of the cæcum with discharge of contents and gas into the peritoneum; another supra-umbilical incision proved the absence of any visceral lesion in that region. The patient recovered.

Starting from the discussion of this case, Chaput passed in review the principal problems involved in the treatment of abdominal wounds; he did not confine himself to wounds made by piercing and cutting instruments, but included also those where the decision is considered far more momentous—gunshot wounds.

And the arguments by which he defended his thesis have so far held good that one is bound to consider them at this moment as having still the same weight as when he spoke.

The crux of the argument can be thus stated: must one wait to intervene in a case of penetrating wound of the abdomen until complications allow us to diagnose a visceral lesion?

"Yes," say Berger and Reclus. Berger had written in 1891: "In recent cases of penetrating wounds of

the abdomen caused by revolver bullets, where there are no complications, in spite of symptoms indicating penetration with more or less certainty, it is advisable to wait, above all when the bullet appears to have involved the stomach or the large intestine." And this opinion he defends by mentioning the signs whose absence justifies abstention: sensitiveness of the abdomen, a certain degree of dulness, a gurgling sound on percussion, frequency of the pulse and respiration, and anxiety of expression. As for Reclus, experimental researches on dogs, experiments which have remained classic, have shown him that a "mucous stopper" can prevent the issue of the intestinal contents through a small perforation, and that the union of an injured loop of intestine to the neighbouring loops favours the spontaneous obliteration, or healing, of larger perforations; finally, statistics concerning 88 injuries treated by waiting, with 66 recoveries and 22 deaths (25 per cent.) incline him to reserve laparotomy for cases demonstrably infected.

Quite otherwise is the attitude of Chaput, already supported by Terrier, Quénu, and Broca, who were joined later by Nelaton and Schwartz. Chaput describes his mode of procedure in terms that admit of no misunderstanding: "Not only do I make use of laparotomy whenever the wound is penetrating, *with or without symptoms*, but I also make use of it whenever penetration is doubtful!" In acting thus he is faithful to the precept: "Act in doubtful cases, whenever action is less risky than waiting."

But, waiting is never without danger!

Too much reliance on the part played by the "mucous-stopper," on the adhesions which limit peritoneal reaction, exposes one to frequent disasters. Limited infection of the peritoneum does not kill, it is true; but Grawitz has shown that wounds of the peritoneum with blood-clot and irregularity of the intestinal surfaces favour the multiplication of germs,

and constantly induce general fatal peritonitis—and that is the case in gunshot wounds of the abdomen.

Is the preliminary diagnosis demanded by Berger always possible? Not at all. There is no "pathognomonic sign" for diagnosing a wound of the abdominal viscera in the first few hours. Pain, early vomiting, pallor, and the pulse have no distinct signification; the temperature is scarcely modified, except in cases of hæmorrhage or shock; hæmatemesis and melæna do not always occur even when the stomach or colon is attacked; the signs of peritonitis are only too slow in appearing. "The truth is," says Nelaton, "that in practice, when the hour of appearance of symptoms has struck it is almost always too late to intervene with safety." Before this "bankruptcy of clinical evidence," laparotomy is therefore indicated as the only intervention really "tutelary." "It is a hundred times better," writes Jalaguier in his turn, "to open an abdomen in which there exists no visceral lesion, than abandon in the peritoneum a perforation of the stomach or the intestine."

But what are the results? What is the respective value of expectant treatment and surgical interference? To the statistics of Reclus (a 25 per cent. mortality by waiting) we may oppose those of Stimson; he gives, not 25 per cent., but 70 per cent.; Chaput also recalls his own experimental researches, which furnish a figure identically the same as Stimson's. Quite otherwise is the coefficient of mortality furnished by laparotomy. A recent thesis, well provided with references, by Adler gives 54 per cent. from gunshot wounds and 32 per cent. for "cold steel" wounds. And this number is still further reduced if we reckon only the early operations by laparotomy, performed in the first five hours!

After noting precisely the operative indications and counter-indications, and describing the technique in detail, Chaput reaches the following conclusions:

1. In the immense majority of cases, with a narrow and recent wound in the umbilical region, it is impossible to diagnose penetration from the symptoms presented by the patient.

2. Exploration by probe and laying open the wound would not furnish us with certainty in all cases.

3. In the case of an abdominal wound dating back several hours, *laparotomy must be performed whenever there is the slightest doubt as to the soundness of the intestine.*

4. If the wound dates back several days, laparotomy must be made use of if there is the slightest doubt as to the possible existence of peritoneal septicæmia.

5. There should be no intervention in the case of a wound dating back twenty-four or forty-eight hours, if the general condition is perfect and there is a very marked sensation of well-being ;

6. Expectant treatment is dangerous. It furnishes a mortality of 60 to 75 per cent.

7. Early and well-performed laparotomy is the only rational and beneficial course. According to Adler's observations, early laparotomy (in the first five hours) correctly executed, has given, in 32 cases, 26 cures and 6 deaths (18 per cent.).

8. It is indispensable to examine the whole intestine so as to be quite sure of not leaving in the abdomen one or more undetected perforations.

9. To find the source of a hæmorrhage easily, to flush the peritoneum in its innermost recesses, it is necessary to turn out the whole intestine.

10. To repair the perforations we must make use, according to the case, of suture in two stages, of intestinal grafts, of lozenge-shaped excisions, and even of resection of the intestine.

Of these conclusions there is not one that has not been confirmed by facts during the last twenty years. Expectant treatment, even " armed " expectation, has lost its last adherents ; under the guise of a seduc-

tive term it has yielded too many deceptive surprises. So that *at the present moment we may consider the doctrine of systematic interference as definitely established; intervention, as early as possible in every case of abdominal wound, whether from cutting or piercing instruments or gunshot, which is liable to be penetrating, with or without visceral lesion.*

But if, *in time of peace*, such a rule is universally admitted, it is because the wound, the patient, the surgeon and the operating theatre present a certain number of conditions that it will be of interest to consider, before dwelling on those that obtain *in time of war*.

In time of peace the *wound* is usually single. One thrust of the sword or dagger generally suffices to calm the fury of a single combat, just as one shot from the revolver assuages the fury of a *crime passionnel*, revives the taste for life in the amateur suicide, and represents the full extent of an accident. The effective force of the projectiles cannot be compared to that of the arms used in warfare. Therefore the wounds received in time of peace are, generally speaking, less numerous, less extensive, and less serious.

The *patient* also is generally overtaken in the full course of his normal life. He has suffered no exceptional privations, his power of resistance is not weakened by a physical strain of several weeks or several months, he is not predisposed to shock by intense and repeated emotional ordeals. It is simply a question of an accident to a healthy subject.

The *surgeon* is a surgeon by vocation, usually accustomed to all difficulties by long practice. And that is a point on which Chaput dwelt with emphasis, as also did Championnière. "He must be a surgeon by profession," said he, "to plunge into this class of operations, perhaps the most difficult in surgery; and I would not advise even a surgeon to operate if he had not sufficient experience in abdominal operations,

and above all of operations on the intestines. Good assistants are also indispensable, and it is necessary that they should have assisted at abdominal operations before." In our large towns all these surgical conditions are present.

The *operating surroundings* not only mean the installations in the local hospitals and the perfection of instrumental appliances; the exigencies of aseptic surgery are provided for wherever one operates, wherever one has the "right" to operate. And from the moment of the accident everything, in time of peace, concurs to favour the sufferer from a wound of the abdomen. As soon as the drama is accomplished the alarm is given; the ambulance arrives, and transport is effected rapidly and comfortably. At the hospital all intended operations are deferred in favour of this "urgent" case, this "interesting" case. Every one makes haste, but only in the interest of the wounded man, and not simply to finish with him without delay in order to give attention to others equally urgent. . . . It is a fact that, in time of peace, the patient with an abdominal wound has the rare, the exceptional fortune to be an urgent case—yes, but, above all, *one* isolated case, *one* single case.

Nothing, therefore, is more natural than that all should be willing and anxious to afford him every chance of recovery.

Nothing is more reasonable than to advocate invariable intervention in doubtful cases, even if it must be purely exploratory.

Nothing is more justifiable than the observation of this rule without the slightest exception.

CHAPTER II

THE FACTS AND PRACTICAL CONCLUSIONS DERIVED FROM FORMER WARS

WHAT a remarkable contrast exists between the history of the treatment of wounds of the abdomen in time of peace and that of their treatment in time of war! The first shows progress, sometimes slow but always proceeding towards the conquest of a decisive and definite formula; here we have facts more emphatic than the words of men; we have results that draw our operators on to bolder attempts; we have practical successes preceding the conclusions of theory.

But the evolution of ideas with respect to the wounded in war is quite another story! It is characterised by repeated fluctuations, nay more, by rhythmic variations. In times of peace surgeons, rendered more enterprising by their daily successes, cannot conceive that war may be a cause of inaction, and declare themselves more and more converts of intervention. But a war occurs; they wish to operate, they do operate, and the results bring brutal discouragement to the warmest partisans of intervention! Then little by little, in peace-time, these disappointments are forgotten; it seems possible to do better; a new wave of courage arises, which a new war will again disperse. . . . These facts incline men to modesty, surgeons revolt against results, and practical experience holds theory in leash. . . .

It is not without interest to retrace the curve of these fluctuations, if only to bring out more forcibly

what is specially noteworthy in the evolution of ideas that has occurred in the course of the present war. For the first time the number of the advocates of immediate surgical action has increased in the midst of war.

It was the War of Secession (1866) that saw the beginning of laparotomy in the treatment of war wounds. At that epoch Billings was its warm partisan. But of ten patients operated on, nine died (90 per cent. mortality), while Nancrède registered a 66 per cent. mortality among those not operated on. But at that period the uncertainty of laparotomy was so great, even in time of peace and when surrounded with every precaution, that the same reasons are of weight here as those that guided us in the previous chapter, making us take into consideration only the facts of the last twenty years. We shall therefore draw our conclusions only from the war in the Transvaal, that in Manchuria, the Morocco campaign, and the Balkan Wars.

We must also indicate the state of opinion on the subject before the war in the Transvaal.

The disasters of Billings and his fellow-surgeons in the course of the war of Secession, as we remarked above, did not deter the laparotomists from taking up the cudgels again !

In 1888, at the Paris Congress of Surgery, Chauvel,* in the course of his report on the mode of action in wounds of the visceral cavities caused by gunshot wounds, takes into account the circumstances of the battle-field, and shows the necessity for laparotomy. On the other hand Delorme, emphasising the difficulties of the time and surroundings, resolutely advocates abstention.

From logical premises the majority of authors declare

* Chauvel, "On the Course of Procedure in Wounds of the Visceral Cavities caused by Gunshot Wounds" (*Report of the Third French Congress of Surgery*, 1888).

themselves in favour of intervention. Several collections of cases serve as the basis for their deductions. MacCormac in England, and Nancrède, Parkes, Hamilton, and Kinloch in America, had shown that spontaneous recovery, if possible, was yet extremely rare, and hardly over occurred except in lesions of the large intestine, almost never in those of the stomach and small intestines. Makins, Flockmann, Fingel, and Wieting considered extraperitoneal wounds the most dangerous because of the greater virulence of the stercoral inflammation and of possible septicæmia. MacCormac insisted particularly on the gravity of vascular lesions; the wound of a small artery or of an inconsiderable vein may become, in the conditions peculiar to the abdominal cavity, the source of fatal hæmorrhage.

The results of the Tonkin campaign, though negative, were the first to give rise to a judgment in favour of operation. Nimier compares the results of 72 abdominal wounds observed during the campaign, none of which were operated on, with the results of 81 laparotomies in civil practice; the former showed a 75 per cent. mortality, the latter only 62 per cent. Nimier concludes that immediate laparotomy is necessary even in war wounds.

Such is the general opinion; the differences of view arise almost invariably as to the most opportune place for surgical interference, whether at the dressing-station (Senn, Kocher), at the ambulance (field hospital) (Nimier, Laval, and Hildebrandt), or at the country hospital (Wagner, Habart).

At this stage of opinion three wars took place:

The Chino-Japanese War of 1893–5 made Haga reject laparotomy as impracticable and useless. Among 52 wounded men medically treated, he observed 75 per cent. mortality; but the only two operations carried out were followed by death.

After the campaign of Cuba the majority of Ameri-

can surgeons (Girard, Beckman, Delatour, Nancrède, and Rudberg) condemned intervention, the wounded recovering without it and dying in spite of it. While medical treatment gave 12 recoveries in 41 cases, laparotomy was tried ten times and was followed by 9 deaths (Roberts: 5 cases, 5 deaths). Although the circumstances and the time of interference are not indicated, these results manifestly tell in favour of abstention.*

During the Tirah campaign eight cases of men wounded in the abdomen were observed (Whitehead): 5 laparotomies resulted in 5 deaths; 3 cases treated medically resulted in 3 recoveries.

In spite of these unfortunate attempts, on the eve of the Anglo-Boer War Colonel Stevenson, professor of Military Surgery at Netley, in a communication to the Congress of the British Medical Association, made an urgent appeal for intervention. Only one of the surgeons present, Surgeon-General O'Dwyer, made reservations regarding the opportunity for the operation. The war in the Transvaal broke out soon afterwards.†

From the beginning laparotomy was frequently employed for abdominal wounds; sometimes, however, under conditions which condemned it to failure beforehand, a point to which we shall return later. There are no official documents stating the number of interventions; but, judging from partial statistics, a fatal issue was the rule and recovery the exception. Post-operative mortality was higher than 95 per cent.

* "Wounds of War caused by Gunshot in the Army of the United States in 1898 and 1899 (Report)" (abstracted in *Arch. Méd. et de Pharm. Milit.*, 1901, vol. i. p. 332).

† Numerous particulars in the following pages have been borrowed from Doche's very interesting study, "Indications and Operative Results on Penetrating Wounds of the Abdomen caused by small War-projectiles" (*Revue de Chirurgie*, August 1909).

We cannot, however, group or interpret the facts in the same manner, which is directly opposed to speedy intervention.

The other works that we have personally consulted will be found mentioned in the footnotes.

Roberts told the British Medical Association in 1902 that he had only seen laparotomy successful in two cases during the whole course of the Anglo-Boer War.*

Partial statistics by Makins of 15 men wounded in the abdomen give the following details: of 13 medically treated, 10 recovered; the two who were operated on died.

Watson Cheyne only performed laparotomy once. It was followed by death; of 11 others wounded, 4 recovered spontaneously.

In opposition to these failures of primary laparotomy, other partial statistics show (with a few exceptions) the happy results of the medical treatment of wounds. Treves estimates their mortality at only 40 per cent. Küttner had 11 deaths in 25 cases, or a mortality of 44 per cent. Flockmann, Ringel, and Wieting give the results as 50 per cent. Herz and Hildebrandt are the only ones who raise the coefficient to 70 or 80 per cent.

Is it astonishing that after the war even those we have mentioned as detractors of medical treatment became advocates of abstention, or showed themselves very lukewarm as regards intervention?

No conversion of this kind is more characteristic, and none has been more exploited than that of MacCormac! A determined partisan of laparotomy, he had the courage frankly to avow his discomfiture. "*A man wounded in the abdomen,*" he said before Küttner, "*dies if he is operated on, in this war, and he remains alive if he is left in peace!*" The suppression of the words "in this war" has allowed men to give an absolute value to this relative formula, and under the title of *the aphorism of MacCormac* to make of it a systematic condemnation of immediate interference in wounds of the abdomen in time of war!

We must, however, remark that if Treves, Dent,

* Roberts, "Treatment of Wounds of the Abdomen in Time of War" (*Brit. Med. Journal*, October 4, 1903, p. 102; *Arch. de Méd. et de Pharm. Milit.*, 1903, vol. i., p. 184).

Flockmann, Ringel, and Wieting are inclined to temporise, they still advocate operation in cases of profuse internal hæmorrhage, or escape of fæcal matter and peritoneal infection.

Makins advises intervention without exception in antero-posterior and transverse gunshot wounds involving the zone of the small intestine.

This is a very important first step in the direction of favouring primary laparotomy, even in the unfavourable light of a recent war.

The work of slow crystallisation which, in time of peace, draws together the partisans of intervention will be easier to describe.

In 1901 a warm advocate, Belin Flagg, at the Congress of the Association of Medical Men of the United States, tried to reinstate laparotomy as a primary operation in war-time. In the same year Morkovitine in Russia, and in 1902 Hildebrandt, at the Congress of German surgeons, showed themselves warm defenders of laparotomy.

Von Hippel,* who so late as 1903 published the conclusions he had formed during the Transvaal War, recognises as indications for primary laparotomy :

(1) Internal hæmorrhage, if the general condition is not too low ;
(2) Wounds of the gall-bladder and of the bile ducts ;
(3) Laceration of the bladder with osseous lesions ;
(4) Antero-posterior or transverse gunshot wounds in the zone of the small intestine or of the transverse colon, *even in the absence of all sign of intestinal lesion* ;
(5) Wounds in any direction with evident intestinal perforation. Secondary laparotomy is indicated in all cases of generalised peritonitis.

* Von Hippel, "Laparotomy in War-time" (*Arch. f. Klin. Chirurg.* lxiii. 3, 1902 ; *Arch. de Méd. et Pharm. Milit.* 1903, 1, p. 181).

In 1904 Lejars declared that intervention is, in his view, "the only chance of safety for a great number of cases of abdominal wound."

On the other hand, Nimier has developed leanings towards abstention.

. . . . .

Surgeons were thus divided in opinion when the Russo-Japanese War broke out (1904). On his arrival at Moukden, the médecin principal Follenfant,* French military attaché, learned from the Russian doctors, and above all from Wreden, that at the beginning of the war some surgeons of the field-hospitals, believing themselves justified by the comfort of their operating-rooms, the completeness of their surgical outfit and the perfection of their material for dressings, ventured on some difficult primary interventions, such as laparotomy; but the resulting want of success compelled them to adopt total abstention.

"Wreden, at Liao-Yang, found himself in a position to try this operation several times; but the repeated failures that resulted made him renounce it altogether, and even to advise his subordinates against it."

At Moukden a certain number of hospitals, directed by Kahoumoff, Davidoff, Œttingen, etc., and superintended by Wreden, received from the front, hardly more than 30 to 40 kilometres distant, the most severely wounded men. These hospitals were intended for special surgery, they were in the most favourable positions, and were worked by a select staff; yet all the laparotomies undertaken were followed by death.

"Princess Gedroïtz alone, operating in a railway-carriage operating-room, had several successful laparotomies; but her patients had the benefit of arrangements admirably suited for the operations and the

* Follenfant, "The Russo-Japanese War. Surgical Impressions" (*Arch. de Méd. et de Pharm. Milit.* 1906, ii. p. 57).

after-attendance necessary. Yet Princess Gedroïtz fixes, as the extreme limit for primary operation, three hours after the injury, and the certainty of abundant hæmorrhage as the determining reason for the operation."

On the Japanese side, Haga,* remembering the Chino-Japanese War, and, as we have seen, opposed to operation from that time, had formally forbidden it to the surgeons at the front. He was not able to undertake it himself because of the great instability of the country hospitals.

At Port Arthur, on the other hand, permanency of the surgical establishments allowed of the systematic practice of laparotomy; but the results were by no means favourable.

Manteuffel † was also inclined to advocate restrictions. "Wounds of the bladder have been considered, since the Boer War, as insistently demanding operation. Bergmann classes them under urgent operations, like tracheotomy, etc. This practice, while beneficial for shrapnel-wounds, is worthless for bullet-wounds. The latter recover very well, in spite of all kinds of fistulas."

What, in comparison, is the general evolution of wounds treated medically ?

Some consider it as particularly favourable. Kholini furnishes a list of 27 cases, with only one death ; this is a percentage of the very lowest order. It is higher with Sonnenblick and Logachkine, who, at Turenschen, report 7 deaths in 25 cases, or 35 per cent.

But these figures require an important correction.

* Haga, "Some Precepts from the Russo-Japanese War" (*Militärärtzliche Zeit.* 1908, p. 424; *Arch. de Méd. et de Pharm. Milit.* 1909, No. 7, p. 33).

† Von Manteuffel, "Medical Practice on the Field of Battle and in the First Lines (Russo-Japanese War). German Congress of Surgery" (*Arch. f. Chirurgie*, 1906, p. 711; *Arch. de Méd. et Pharm. Milit.* 1908, 11, p. 443).

As Bornhaupt * observes, "One would have to know not only about the wounded who arrive at the field-hospitals behind the lines, but also about those who succumbed before arriving there." Follenfant estimates them at 20 per cent.: "Abundant peritoneal hæmorrhages have been only rarely observed, but it is certain that one-fifth of the penetrating wounds of the abdomen have caused speedy death in the mobile hospitals and ambulances at the front."

And here, taken from Bornhaupt, are statistics in which all the figures have their significance. In his Red Cross hospital, which was a base hospital, he received 174 patients wounded in the abdomen, who were admitted from the sixth to the tenth day. He divides them into three categories.

First category.—Of 118 cases treated by abstention, three who had violent peritonitis succumbed; the others recovered; which is splendid! But of the latter number only 13 had pronounced visceral lesions, and 89 *presented absolutely no abdominal symptoms.* . . . We see the value of the coefficient of 2–3 per cent. mortality arrived at by certain authors!

Second category.—Five cases of penetrating thoraco-abdominal wounds give 4 deaths.

Third category.—41 cases include 18 wounded already operated on at the front, 2 deaths; 27 laparotomies undertaken at Bornhaupt's hospital, 14 recoveries, 13 deaths. It must be remarked that these brilliant results only concern deferred laparotomies, partial ones, probably for purulent localised peritonitis. Kablouchkoff noted equally with Follenfant the great number of recoveries observed at the base under these conditions.

Bornhaupt's conclusion is nevertheless as follows: "It is no longer possible to maintain now the principle

* Bornhaupt, "On Gunshot Wounds of the Abdomen during the Russo-Japanese War, 1904–5" (*Arch. f. Klin. Chirurg.*, résumé in *Arch. de Méd. et Pharm. Milit.*, 1909, ii. p. 234).

of absolute primary non-intervention, and one must no longer regard as a dogma the aphorism of MacCormac."

To judge of the comparative gravity of lesions according to their locality, we have the statistics of Kharbine (1904):

Lesions.	No.	Deaths.	Recovery at once.	Discharged.	Mortality.
Stomach-intestine . .	254	42	69	125	16%
Liver	31	6	1	24	20%
Spleen	7	1	0	6	7%
Kidneys	1	—	—	1	—
Bladder	14	4	1	9	28%

(The number of subsequent laparotomies performed in the base hospitals is unknown.)

The coefficients are of small value, for two reasons: they only register a provisional mortality, since one does not know the fate of the discharged, and the different parts of the intestine are grouped, though there is a primordial interest in separating the small intestine and the colon.

More importance ought therefore to be accorded to this statement of Follenfant: "As always happens, perforations of the stomach, the upper portions of the small intestine, and those of the bladder have caused far higher mortality than wounds of the large intestine and the lower portions of the small intestine."

. . . . .

The Morocco campaign did not produce many new facts. "Only one primary laparotomy has been performed to our knowledge," writes Doche, "in consequence of an attempted suicide, and the lesions were such that, in spite of intervention, the wounded man succumbed in a few hours." Toubert noted, at the principal base hospital at Casablanca, three cases of penetrating abdominal wounds in a total of

about 200 wounded, or 1·5 per cent. (which does not mean that there were few men wounded in the abdomen in the battles, but that nearly all died on the spot or in transit). The three cases of penetrating wounds recovered, two of them after having been complicated by suppurating retroperitoneal hæmatoma, and with a pre- and peri-vesical abscess with hypogastric fistula (none of these cases, it would seem, was accompanied by lesion of the intestinal canal).

Gauthier, for his part, has communicated a statement concerning 22 abdominal wounds, without primary interference, among a total of 194 men wounded in war whom he looked after in the hospital at Casablanca, or at the field-hospital at the Boucheron camp; but from these 22 cases 14 simple parietal wounds should be deducted. There then remain:

	Case.	Death.	Recovery.
Perforation of the intestine .	1	1	—
,, ,, ,, liver . .	3	2	1
,, ,, ,, bladder .	1	—	1
Section of the internal iliac vessels	2	2	—
Without important visceral lesions	1	—	1

Thus 11 penetrating wounds show 5 deaths, or 46 per cent. But we must bear in mind the special conditions of transport for long distances, by the primitive means of cacolets or "arabas." This state of things would only permit of those coming in alive who were, truly speaking, very tenacious of life!

If from these results we are bound to conclude that they support the theory of medical treatment as opposed to laparotomy, we must remember that they occurred in wars and under strategic conditions which rendered any immediate surgical interference out of the question.

. . . . .

The Balkan Wars gave rise to almost identical statements, all having very slight encouragement to hold out as regards laparotomy.

Consergue * writes: "The statements made during the Anglo-Boer and the Russo-Japanese Wars have again been verified in the course of the Balkan War: penetrating wounds of the abdomen from projectiles of small calibre, when left to themselves, heal in surprising numbers, even when complicated by lesions of the kidneys and liver. The following statistics are in themselves convincing:

"Belgrade Military Hospital: 28 penetrating abdominal wounds, 8 immediate deaths, 8 deaths after interventions for localised peritonitis, 18 recoveries, 6 of them after intervention.

"Russian Red Cross Hospital at Belgrade: 10 cases, 10 recoveries, 4 of them after operations for circumscribed peritonitis.

"French Hospital at Salonica: 7 cases, 6 recoveries without intervention, 1 death."

Véras † was struck with the rarity of abdominal wounds and with their simple evolution. The 4 or 5 cases he observed all recovered without operation, but they all arrived, on an average, three days after the date of their wound. . . .

According to Le Fort,‡ abdominal wounds were "very rare in the hospitals of the interior, and they progress most frequently in the same manner as simple wounds, even after hæmaturia, mèlæna, or some other symptom has shown the penetrating nature of the wounds. Laparotomies are absolutely exceptional, unless this term is applied to incision of abscesses formed around projectiles. . . . If the circumstances," he adds, "allowed of active surgery at the front,

* Consergue, "The Balkan War. Organisation and Work of the Service de Santé in the Allied Armies" (*Arch. de Méd. et de Pharm. Milit.*, August and September, 1913).

† Solon Véras and Le Fort, "Four Months in Montenegro during the Balkan War" (*Arch. de Méd. et de Pharm. Milit.*, May 1913, p. 522).

‡ Le Fort, "The Service de Santé in the Balkan War" (*Arch. de Méd. et de Pharm. Milit.*, April 1913, p. 432).

it seems to me that the attention of the medical men should be directed to cranial surgery, and not to abdominal surgery (even in automobiles de luxe)."

The remarks of Delorme,* to which his great authority gives singular impressiveness, are, on the other hand, alarming: "Curious and striking instances of uncomplicated recovery should not make us minimise the immediate or rapid urgency of abdominal wounds, notwithstanding the less frequent and less pronounced rupture of vascular viscera, and hollow organs at relatively short distances. Even at medium, and still more at long distances, the perforations are narrower, and spontaneous occlusion is possible in the stomach, intestine, or bladder. The surgeons at the front will inform us of their relative frequency, their real gravity, and will give us all the needful particulars; but it would be a singular error to suppose that a bullet could traverse an abdomen with impunity, as these happy recoveries have caused too many to maintain. As a matter of fact, abdominal lesions have been very rare in the various base hospitals. . . ."

Reverchon has also been good enough to furnish us with the following remarks: "All those with abdominal wounds were retained in the dressing-stations at the front. In the various convoys passing into the station of Scoplje I did not observe a single one. But when I arrived at the front, hardly eight hours after the last serious combat, there were no wounded of this kind left in the ambulances; their fate was settled. . . . How ?

"The results of laparotomy were not brilliant. As in all other wars, the surgeons made systematic trial of it, especially at the beginning. Cohen, after Krivolack, operated on men after thirty-six hours, and six hours of transport—he had one survival in

* Delorme, "Precepts of the Balkan War (Campaign of Thrace, 1912). (Evacuation, Wounds from Instruments of War)" (*Acad. of Medicine*, April 1st and 22nd, 1913).

twelve operations. He only operated in undoubted penetrating lesions. Interventions in confirmed peritonitis did not result in a single recovery, notwithstanding the use of rectal saline and the sitting position. Similar results were obtained elsewhere. The first part of MacCormac's aphorism is therefore confirmed: 'Those wounded in the abdomen by small projectiles died when they were operated on.' But the second part of the proposition, 'Those who were not operated on survived,' has not been realised.

"The abdominal wounds received in the course of the second Balkan War were extremely serious. I certainly have seen survivors, notably two cases in which penetration was proved by a slight peritoneal reaction. But was there an intestinal lesion? We may doubt it, or at least we may admit that there were not multiple perforations of intestinal coils, as the direction of the wound was what I should call 'superficial perforating,' anterior in one case, posterior in the second.* On the other hand, all the Serbian and Bulgarian doctors I have questioned in the course of my journey have made the same answer: 'I have not seen *one single case* of antero-posterior or slightly oblique shot-wounds in the umbilical or para-umbilical region, indicating multiple lesions of the intestinal coils, recover without operation.'

"In a word," concludes Reverchon, "the question remains open. Systematic abstention has only the value of a provisional dogma!"

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Whatever partiality one might entertain in favour of laparotomy, one could not, in truth, draw encouragement from the preceding wars. Would it not be

* *First case.*—Entry on the median line, midway between the umbilicus and the xiphoid: exit in the nipple line in the vicinity of the costal border. *Second case.*—Entry in the right lumbar region, 15 centimetres from the median line, in the 11th intercostal space, a little outside the margin of the kidney; exit on the left flank, less than four inches outside and above the umbilicus.

possible to find reasons for the almost invariable failure of primary intervention? And what is the precise value of the success attributed to medical treatment?

. . . . .

Recoveries by abstention are undeniable. That is the first point.

A lesion of the intestinal canal that had shown itself by hæmatemesis, followed by melæna, and even by the passing of the bullet by the anus, has nevertheless been followed by recovery. Makins, W. Dick, Marche, and MacCormac have seen indisputable lesions of the stomach thus healed, Mathiolius has seen it in the kidney, and MacCormac in the ascending colon. One of Haga's wounded passed the projectile by the rectum at the end of five days, and another at the end of three years. More frequently still the perforation has been closed in the course of an operation for localised peritoneal infections, following a lesion of the intestine.

The mode of healing in such cases has been experimentally studied in time of peace (Reclus and Noguès, etc.), and the operative investigations in time of war are of peculiar interest as verifying the process. It results from the narrowness of the wounds produced by bullets of small calibre * from the empty state of the canal, and from the usual absence of extravasation of the intestinal contents (direct observations of MacCormac, Treves, Mathiolius, Follenfant, and Whitehead); the perforation remains impervious owing to the contraction of the muscular wall, to a hernia of the mucous membrane which is soon covered by

* "An exception must be noted when the firing is at close range. The destructive effect of the projectile on the intestine is then enormous. It is split and mangled, the continuity of the intestinal tube is interrupted at several points, and fragments of the bowel are scattered in the abdominal wall (Wreden). The greater number of these wounded, remain, moreover, on the field of battle (Hildebrandt)" (Doche).

a fibrinous material (Follenfant, Ringel), and to the adhesion of the wounded loop to the neighbouring coils (Follenfant, Lardy, Haga).

But is this spontaneous repair of visceral lesions as frequent as it is asserted to be ?

The cases in which the projectile can traverse the body without wounding any part of the digestive tract are numerous. After Lebel's personal experiments of bayonet-wounds on recent corpses, taking into account Reclus's experiments with revolver-shots at dogs, Sieur estimates that in 15 per cent. of cases, at least, a bullet can traverse the abdomen without injuring one of the viscera that it contains. Observations made in time of war corroborate this. After the war in the Transvaal, Bowlby, Makins, and Hildebrandt reported instances of it.

Equally numerous are the wounds of the abdomen wrongly classified as penetrating, which nevertheless serve to establish a high percentage of cures by abstention. Have we not seen, for example, that in 118 cases observed by Bornhaupt, 89 presented absolutely no symptom of perforation ?

Infinitely more numerous, again, are the cases of men wounded in the abdomen who died before they could be registered in the published statistics. These statistics, in fact, nearly all come from the base hospitals ; it is sufficient for us to recall the long delay before the wounded arrive at the surgeon's station. Bornhaupt reckons it at the sixth to the tenth day, Véras at the third day, Cohen and Reverchon at thirty-six hours, of which six are occupied in transport ! Follenfant estimates the number of those who die between the dressing-station and the base hospitals as 20 per cent. And this without taking account of those there has not been time to remove from the field of battle ! The only statistics of real value would be those coming under the observation of the doctors in the posts nearest to the front, and

those seen by the surgeons stationed in intermediate positions between the front and the base. In no war has such a record been made, and, if it were ever attempted, it would still be necessary to take into account the errors of diagnosis inseparable from abstention!

Real as are the successes of medical treatment, we must not ascribe to them a fictitious importance; where the intestine has been involved, recovery has been rare.

And for us, who are seeking in the experiences of earlier wars for instruction that may be of use to us in the present war, there is one important detail that cannot be too strongly insisted on. In former wars—Delorme himself has pointed it out—*it was the rifle-bullet that put the greatest number of soldiers out of action!* Shrapnel wounds were rare, and there was no question of the bursting of percussion shells. The same fact increases in our eyes the rarity of spontaneous healing that can be considered due to abstention, since only bullet-wounds can be thus healed, while the number of wounds due to shells increase every day.

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Now let us ask, *What are the causes of the failure of laparotomy in war?*

There is one that dominates all the others—*the delay in intervention.* During the Chinese campaign of 1900 Haga kept account of the time of arrival of the wounded at the hospital; the average interval was nine hours, while some only arrived after twenty-four hours. On arrival nineteen out of twenty-two presented symptoms of peritonitis. Laparotomy was thus doomed to failure.

In the Transvaal, Neale excised successfully thirty centimetres of intestine which was divided and perforated; but this took place only six hours after the man was wounded. Von Hippel has compared the results of six laparotomies performed in the first

twelve hours and those of ten others carried out at the end of the thirteenth hour, or on the second, third, and fourth day, after prolonged transport. The first gave 3 recoveries and 3 deaths ; the latter, 1 recovery and 9 deaths !

We have already mentioned a success by the Princess Gedroïtz in Manchuria ; but the colonel whom she thus saved was operated on between four and five hours after he had been wounded ; he presented two perforations of the intestine and section of a mesenteric artery ; after the operation he was so anæmic that it was necessary to give frequent injections of saline, and for ten days he was in a dying condition ; in the end he recovered (Follenfant). But what would have been the result had the operation been delayed by one hour ?

In the Balkans Cohen, who was a surgeon in the Danube division at Kumanovo, saw a man who was wounded in the abdomen at the commencement of the battle ; it was a case of para-umbilical gunshot-wound. The operating-theatre was empty. the wound was only an hour and a half old. He sewed up seven or eight perforations in the intestine. The patient was carefully deposited in a bed in the train that waited by the side of the ambulance, and at once transported to Belgrade, where he recovered (Reverchon).

The *material conditions* under which laparotomy is performed in the vicinity of the field of battle are often most precarious. In the Transvaal they had to instal themselves in farms, often in the open air. The country swarmed with insects. Treves reports that during laparotomies the intestines were black with flies, while the wind brought clouds of dust to the wounds in squalls ; they operated on biscuit-boxes ; they were short of water.

Still, not all operations were carried out under such disastrous conditions. MacCormac, Makins, Watson, and Roberts had at their disposal a surgical equip-

ment and sterilising material that were perfection. It was the same in the case of the foreign surgeons who were present at the war as members of the Red Cross Societies, like Küttner, Habert, Mathiolius, and Herz.

In Manchuria, Follenfant * very judiciously observes that "for the first time the circumstances were very favourable for efficient collection and transport. These circumstances will most probably be repeated in future battles. They included the slowness of military offensive operations and the prolongation of the resistance, the use of the railway on the field of battle, the inviolability of the fronts and the temporary security it ensured." Why, then, were not better results obtained in the case of abdominal wounds?

"It is well to remark," says Follenfant again, "that in the practice of the civil surgeon, operations are only performed very rarely outside the hospital on abdominal wounds. If it is true that with any advantage that circumstances can afford a surgeon may occasionally obtain a splendid result in dealing with a single accident or operation, how different is the situation of the ambulance surgeon—he has to treat a large number of cases in circumstances of the greatest difficulty, at a time when security is uncertain and when conditions are inferior to the very worst of those encountered in time of peace. How is it possible, then, to guard against such infections as we may still meet with in the best-equipped hospitals, and what surgeon could, in these circumstances, hope for a series of successful results?" The successes obtained by the Princess Gedroïtz in her railway-carriage operating-room, reserved for a small number of serious cases, confirm these observations.

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We now find ourselves naturally led to recall the

* Follenfant, *Études sur le service de santé en campagne*" (Chapelot, 1910).

requirements of the surgeons of former wars with respect to the surgical treatment of abdominal wounds.

First comes *the specialisation of sanitary units for the benefit of such serious cases.* Œttingen thinks that abdominal surgery will play a great rôle in future wars, but on condition that it remains in the hands of capable surgeons and is restricted to a very limited number of cases. Bornhaupt declares that the most experienced surgeons ought to be at the field-hospital (ambulance) and that the appliances ought to be of the first quality. Von Hippel proposes the creation of hospitals three or four kilometres from the field of battle, with a specially trained staff; when the operation is over, an ordinary hospital building should be at hand, as discharge could not be expected in less than ten or twelve days. Tomasi had formulated the same idea.

The second requirement is the use of *ambulance trains*, which gave such brilliant results when employed in Manchuria. Not all of them were as luxurious as that of Princess Gedroïtz; the operating rooms were established in ordinary carriages or in goods-wagons. When peace was made a train of this kind was prepared at every important station (Follenfant). In this way an operating-station completely installed and ready for immediate use was provided, and it could be moved as required into the immediate neighbourhood of the fighting region. This is a most inspiring idea, and one that deserves to be put into practice again.

There is, lastly, the *necessity for a hospital on the spot*, quite as much for the wounded who are operated on as for those treated by abstention. Having to turn them out would undeniably aggravate their condition.

At Jacobsdal, in the Transvaal, where the German Red Cross ambulance was installed on the field of battle, nearly all the wounds healed without suppuration; at Spion Kop, on the contrary, where trans-

port was particularly difficult, where the wounded had to be taken down steep descents and over rocks, all the English wounded in the abdomen and moved under such conditions succumbed (Küttner).

During the Chinese campaign, following an evacuation lasting about nine hours, Haga saw 22 patients, of whom 19 presented symptoms of peritonitis on arrival.

In Manchuria, after the fight at Turentchen, 22 wounded, included in the convoy of evacuation organised thirty-six hours after the engagement, had to travel 60 kilometres, either in carriages, on stretchers, or on horseback. Of these 22 wounded, 4 presented symptoms of peritonitis and soon died (Sonnenblick and Logashkine).

Kholini has also remarked on the frequent appearance of symptoms of acute peritonitis following hasty transport in badly hung vehicles.

Similar results occurred in laparotomies. Brentano saw those operated on in Manchuria arrive at the hospitals of the second line only to die.

If the patient operated on by Cohen suffered no harm from removal, it was because that took place immediately after the operation, and in one of the best suspended cots.

"The man wounded in the abdomen dies," writes Reverchon, "particularly if he is operated on too late and undergoes too many removals and transhipments."

"The delay between the traumatism and the operation should be shortened as much as possible, and the evacuation before and after must be perfected."

. . . . .

If we now glance at the history of the treatment of abdominal wounds in the course of the wars of the last twenty years, two essentially practical ideas seem to stand out from the mass of facts, and confirm the impression that we recorded at the beginning of the chapter.

First, immediate laparotomy has nearly always disappointed the hopes of even the most favourably inclined surgeons, and the boldest. It still retains adherents, however, who count on the development of better organisation and conditions for the attainment of more frequent successes.

Again, abstention is followed by genuine recoveries, but a close examination of the results shows that *successes are much rarer than has been thought,* and perhaps there is a call to revise the technique of laparotomy.

The question, therefore, remains open. The experience of the war now in progress is bound to furnish new elements for discussion and decision.

CHAPTER III

THE EXPERIENCE OF THE PRESENT WAR

THE facts observed and the works published between the outbreak of the war and the present moment seem naturally to divide themselves into three periods.

In the *first period* it is admitted without question that laparotomy is disastrous. That is the undisputed verdict. On the other hand, what is the outcome of purely medical treatment? In this respect, opinions differ. Some claim an important proportion of recoveries; others, on the contrary, register a depressing quantity of failures. As to surgical interventions, they are limited to drainage of the area or to preventive supra-pubic aperture with drainage of the pelvis, called "Murphy's operation." This is also the period of anastomosis, of multiplied openings for drainage, etc.

The *second period* is marked by a very distinct reaction in favour of laparotomy. A close analysis of the statistics concerning abstention shows the greater part of the successes registered concern wounds either non-penetrating or without visceral lesions. Laparotomy now begins to register successes, and these successes prove that a good surgeon can, by operating, "at a period soon after the wound has been received and in favourable conditions, deal successfully with abdominal wounds which, without his intervention, would prove fatal" (Quénu). Corroborating facts begin to multiply. Two ideas stand out—it is untrue that laparotomy entails nothing but disasters, and it is untrue that abstention produces frequent successes.

A *third period* follows, in which there is again a reaction in favour of medical treatment. Impressive statistics again appear, and by the nature of the cases and the professional rank of those who publish them, endeavour to demonstrate that surgical treatment by laparotomy is only practicable in exceptional circumstances, that its employment is not to be generally recommended, that recourse must therefore be had to abstention, and that practically medical treatment affords numerous successful results. But here again criticism steps in and shows once more that the recoveries observed are very doubtful from the point of view of penetration and of visceral lesions; it maintains, besides, that to submit tamely to materially defective conditions is no solution, and that an efficient organisation ought to be substituted for an inefficient one.

That is where we stand at present.

It is important to remark that these three periods coincide approximately with three different phases of strategical conditions; a sort of parallelism, which is easily comprehensible, exists between them.

During the first months the war was one of rapid displacements and of great masses; fighting occurred daily; retreat was going on, and even when the retreat was interrupted, the uncertainty of the immediate future necessitated instant evacuation to a point as far as possible from the front; the multitudes of wounded overcrowded the sanitary installations, still badly organised; the means of transport were primitive; the equipment was insufficient and badly distributed; the staff was inexperienced and without cohesion, while a strange fantasy and forgetfulness of specialisations seemed to have presided in the utilisation of the various departments. Is it astonishing that laparotomy under such conditions was followed by disasters?

But the war of the trenches follows the war of

movement; the adversaries are stationary; they no longer move from place to place; their change of position is measured in yards and not in miles. The ambulances, immobilised, complete their equipment, and the hospital conditions of the wounded improve; automobiles carry out the transport of the wounded to the surgical centre where they can be operated on more easily and more rapidly; operating staffs are organised. Laparotomy finds the conditions necessary for effective action. It ought now to repeat its successes and to regain its credit; it does so. More than that, the installations of the laparotomists are at last established in the immediate vicinity of the front; the interval between the wound and intervention is reduced to a minimum; all these influences make themselves felt, and statistics improve.

Meanwhile the almost regular war of the trenches gives place to surprises, to unexpected attacks, to combats murderous in their effects, even though their front is not of great extent. The material conditions that necessitate a series of laparotomies are overthrown; abstention has perforce to be observed. Then, in September 1915, an attack of great extent reopened the question of the possibility of operations on the abdomen at the moment of great battles, or where the evolutions are by advance *en masse*. The difficulties that the practice of laparotomy have now to overcome have again to be faced by its numerous partisans.

We shall find these different modes of considering the problem set forth as we examine one after the other the works published during the three periods that we have just sketched.

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First Period.—The experience of former wars, as we have said, had led surgeons to consider MacCormac's aphorism as a dogma, or at least the first part of it. The doctrine of abstention reigned paramount at the

outbreak of the present war; it was insisted on at the Val-de-Grâce; it was accepted by all or nearly all military surgeons.

All attempts running counter to this dogma were considered to be so definitely doomed to failure and exposing those wounded in the abdomen to such risks, that an administrative circular, dated October 15, 1914, impressively reminded military surgeons that medical treatment alone was to be employed, and that all intervention was to be confined to Murphy's operation. The following is the text of Delorme's communication, which inspired the circular:

"The treatment of *abdominal wounds* with lesion of the intestine merits all the attention of the surgeons, above all that of the surgeons at the front. It has been enriched by numerous resources, still insufficiently known, whose employment should do much to diminish the very fatal prognosis of these wounds. If there is still discussion as to the opportunity for much laparotomy in the abdomino-intestinal wounds of ordinary practice, it is otherwise as regards war surgery.

"*In principle immediate laparotomy is to be rejected.* The most recent wars, those of the Transvaal, Manchuria, and the Balkans, have *shown its ill effects.*

"In the Transvaal, although it was carried out by eminent laparotomists, under the most favourable conditions for ensuring success, it produced far fewer recoveries than operative abstention.

"The German bullet, reaching the abdomen with high velocity, especially at long or medium range, produces a narrow orifice of entrance in the abdominal area, and does not introduce any infecting particles of clothing. In the intestinal coils it only makes very small orifices, and minute perforations which have a tendency to close spontaneously. In certain cases it even insinuates itself between the coils without perforating them. Instinctive evacuation, before going

into action, of the intestine and bladder, the fact that the wounded man remains on the spot for hours, and does not have to undergo the jolting of transport —all these conditions help to prevent intraperitoneal suffusion, or limit it and favour recovery.

"For traumatisms of this character the old methods of treatment seem to suffice: absolute rest, the absence of transport to a distance, complete privation of food, and, above all, of liquid for several days—a regimen that can be supported with the aid of incessant rinsing of the mouth, rectal or subcutaneous injections of artificial serum, and opium, added to the half-sitting position advised by Fowler.

"When, on the other hand, the speed of the projectiles has been greater, when the bullet has 'see-sawed,' or when the wound has been made by the large shrapnel bullet, the *orifice of entry* through the skin, circular or oval, is *larger*; the wound or wounds of the intestines are also larger; they are less susceptible to close spontaneously, and contamination by pieces of clothing is frequent.

"In these cases peritoneal infection is certain, but the surgeon is not without resources. To the treatment already indicated he adds, if possible, continuous instillations, drop by drop, as advised by Murphy; above all, *Murphy's early incision and drainage*, and the cleansing of the peritoneum with ether (Souligoux).

"Murphy's incision is a short button-hole made in the abdominal wall above the pubic arch. By this incision, performed quickly, under simple local anæsthesia and after a very rapid disinfection of the skin with iodine, the pelvic cavity is drained where, in Fowler's half-sitting position, the septic fluids have a tendency to accumulate. This position represents a safety-valve; it anticipates a dangerous tension which would favour the reabsorption of the septic products.

"In 17 cases of shot-wounds with perforation of the

intestine Harris has had, owing to Murphy's incision, 17 recoveries.

"Murphy's conception and technique accord well with the actual practice of the 'Service de Santé' in the ambulances and the country hospitals. It opens to our surgeons a path along which they should resolutely proceed. It is not a complicated operation like classical laparotomy, which a body of qualified surgeons could not repeat more than three or four times in one day without neglecting all the other wounded—a fatiguing operation, increasing the shock, liable to destroy salutary adhesions, demanding a special installation, and minute aseptic precaution, to produce, I repeat, fewer recoveries than operative abstention. It is a very simple act, very rapid in execution, within the compass of every practitioner."—*Communication to the Academy of Sciences*, August 10, 1914.

Some surgeons, and not the least distinguished among them, still opined that there was something better to be doné, and that laparotomy at least deserved to be tried again. Their experiments were, however, not encouraging.

Tuffier had himself to declare later on that only one remained alive of those he had operated on, or caused to be operated on, in the field hospitals at the front, in the Vosges; but he does not give the number of operations.

Picqué[114] recently related how at B—— the first evening of the battle of the Aisne, during the second hour of his improvised installation, he performed on a wooden table covered with oil-cloth, with rudimentary material and aseptic conditions, a laparotomy for the extraction of part of a shell from the iliac fossa, which operation was completely successful. . . . Then he operated, without success, in a series of very critical cases, with extensive multi-visceral lesions

and evisceration, evidently beyond the resources of surgery. He was not disheartened by his want of success, and would have declared himself justified if he could have saved one case in five, until one day when an exceptional case of revolver-shot, brought to him a quarter of an hour after it occurred, proved to him, by its loss, that laparotomy was not possible at the ambulance station without *absolute asepsis and perfect instruments*. He therefore voluntarily ceased all laparotomy, until these conditions could be realised. And in the meantime he observed, among the wounded under treatment by abstention, a spontaneous progress that was always fatal. So marked was this that Picqué remained, theoretically at least, a partisan of intervention.

Sencert [2], on the contrary, declares himself very categorically a defender of abstention. He falls back on three essential arguments: obstruction, shock, and the possibility, even the frequency, of spontaneous healing. He goes so far as to draw up a code for the surgeon in an ambulance at the front when confronted with a penetrating wound of the abdomen: (1) he should intervene in the very rare case of a wounded man "having a large wound in the abdomen with external hæmorrhage, evisceration, and obvious section of the intestine; (2) he should abstain, and adopt 'armed expectation' in the case of a narrow wound in the abdomen; (3) he should make a triple drainage of the abdomen if peritonitis appeared during the following days; (4) if the diffuse peritonitis stops short and encysted peritonitis appears, it must be sought for, located, and opened." Reducing to such a point the very exceptional indications of laparotomy in desperate cases is equivalent to condemning it.

Abstentionist conclusions have also just been defended by Weiss and Gross [3]. Thanks to the situation of the town of Nancy, distant 10 to 15 kilometres from the strategic position of Grand-Couronné,

where important actions have taken place, they were able to observe the wounded at the end of two and three hours, as the latter were brought straight from the firing-line in motors; thus Weiss and Gross were in the position of a regular field-hospital. But by exceptional good fortune they could operate in hospital surroundings specially constructed for surgery—that is to say, in the very best material conditions, whether as regards assistance, equipment, or post-operative care. In spite of all these favourable circumstances, four laparotomies resulted in four deaths. It is right and interesting to consider the results furnished by Murphy's operation (5 cases, 5 deaths) and by medical treatment (57 cases, 49 deaths—the recoveries including five lesions of the small intestine, one lesion of the ascending colon, one lesion of the liver and one vesical lesion). Thus all the laparotomies ended fatally, and Weiss and Gross decide definitely in favour of abstention. In no case, they consider, should laparotomy be undertaken deliberately simply for the discovery of lesions. They limit operative indications as follows: hæmorrhage; intra-abdominal wound of the bladder, in which incision and Murphy's treatment could be made use of simultaneously; drainage or lateral colotomy if a lesion of the large intestine is suspected; incision by thermo-cautery if there is an escape of the intestine through the wound. As to Murphy's operation, it is no more effectual than laparotomy in checking lesions of the peritoneum developing in the first few hours.

Cadenat [10] reports 26 cases of penetrating abdominal wounds in which he intervened 17 times (5 recoveries), and 9 abstentions (6 recoveries), giving a mortality of 70 per cent. with operation and 33 per cent. with abstention. Murphy's treatment afforded him one recovery (in a bullet-wound) in four cases. Hence he deduces the uselessness and danger of suture by laparotomy; he is sceptical about the results of Murphy's

operation (so-called); in short, he considers abstention pure and simple the wisest course. Hartmann, who reports this, contents himself with summing up Cadenat's account without formulating a personal opinion.

Now comes an enthusiastic plea in favour of what Duval calls "the very administrative formula of the supra-pubic button-hole" Devèze's work [7] is an apology for the operation named after Murphy. Thirty-one cases afforded him 11 recoveries. Of these 11 cases Tuffier shows that five times only blood flowed from incision of the peritoneum; twice it was a question of a wound of the large intestine, so that only in 4 cases recovery followed a wound of the small intestine. It is to be noted that in 11 cases 10 of the wounds had been caused by a bullet.

After a lapse of several months we find in a few lines of an article by Miramond de la Roquette [34] another late plea in favour of Murphy's incision. Miramond proposes to supplement it by anastomosis through the skin of an injured intestinal loop by "the opening of an *iliac anus* which assures the drainage of the intestine and prevents the dreaded phenomena of intestinal paresis so frequently met with."

We shall see further on (page 389) what to think of this.

All these are only isolated voices, far off and hardly audible. For it is now quite a long time since the chorus of the interventionists began to collect and to increase in volume.

Second Period.—The hymn to laparotomy covers all the second period. We can distinguish in it three themes: definite condemnation of Murphy's operation; keener criticism of the recoveries attributed to abstention; growing eulogy of laparotomy as the general method of treatment in penetrating abdominal wounds even in time of war. And very rare are the discordant notes that make themselves heard!

First came a cry of alarm uttered by Duport and Kendirdjy [1] at the meeting of the Chirurgical Society in November 1914. "The benefits of abstention are advocated in text books and even administratively. How is it, then, that in 40 cases we register 40 deaths, although 38 of the wounds were from bullets?" And from this time the surgeons began to develop the idea of a special ambulance so that the wounded could be taken rapidly to the dressing-station by automobile and operated on by laparotomy.

They did not confine themselves to theorising—on February 9th, 1915, they made a new communication [4]. This time they reported 4 cases operated on. Among these 4 cases they had 1 recovery. A soldier hit by a rifle-bullet in the lumbar region was laparotomised six hours after the wound was received; five perforations of the small intestine were stitched up. In the other 3 cases the operation ended in death. The first case was a wound at close range from a Lebel bullet and the operation took place an hour afterwards. There were two perforations of the small intestine, besides perforation of the bladder and a wound in the prostate. The second case was an accidental wound from a revolver-bullet. The operation was performed two hours afterwards. There were six perforations, of which two were not discovered. The third case was a bullet-wound; it was first treated by abstention, and operated on nineteen hours after, when the symptoms were fully developed.

At the same meeting Routier read a report on a work by Hallopeau [5] entitled, *The Working of a Mobile Surgical Hospital at the Front.* In this field-hospital Hallopeau had to treat, among other cases, 9 wounds of the abdomen, of which 7 were penetrating. One of the first operated on, brought in with an imperceptible pulse, died three hours afterwards. Of the 6 others, only 4 underwent real laparotomy with investigation of the lesion. The results were as

follows: "2 underwent transverse laparotomy in the region of the liver, 1 of whom died. The other was discharged in a favourable condition 31 days later; 2 underwent a large median incision with evisceration; 1 of them had a wound in the liver and 6 intestinal perforations—he succumbed; the other also had a wound in the liver and a lesion of the duodenum—he made a surgical recovery but succumbed to scarlatina." It would therefore appear that there is no definite recovery from intestinal wound to record.

M. Chavannaz [4], at the meeting held on February 24th, made an important contribution concerning 51 cases in which he intervened 13 times; of the 13 patients operated on, 9 died, which gives a 69 per cent. mortality; of the 38 not operated on, only 22 died, showing a mortality of about 58 per cent. According to these statistics, surgical intervention would appear to give disadvantageous results; but he hastens to add that the mistake of considering as penetrating the wounds that have not affected the peritoneum is easy to commit, especially when it is a question of lumbar wounds. Retaining, then, only the indisputable cases (34), 12 operations give 9 deaths, and 22 not operated on give 20 deaths, which reverses the proportions and shows 75 per cent. with operation and 90 per cent. with abstention. Summing up, Chavannaz is inclined to increase the operative indications, but he would confine abdominal surgery to immobile field hospitals, or even to stationary hospitals placed near the front.

At the meeting of March 24th, returning from a surgical mission "for a new trial in the army of the Marcille sanitary formation" (the formation in which Hallopeau had already obtained the results quoted above) Gosset [5] definitely takes his place in favour of complete surgical intervention. Influenced by the prevailing doctrines, he began by treating medically the first 5 wounded brought to his ambulance; all the 5 died, although 2 appeared only to have slight

injuries. In a second series of 7 wounded, Gosset intervened by laparotomy; of the 7, 4 recovered as follows: A perforation of the sigmoid flexure (bullet-wound operated on eight hours afterwards); a perforation of the liver, the stomach, and the jejunum (bullet-wound, operated on 6 hours after); a wound of the liver and of the right colic angle (hepatic flexure) without opening of the intestine (bullet-wound operated on 29 hours afterwards); a shrapnel wound with multiple perforations of the small intestine, operated on 11 hours afterwards; in other words, 3 cases of perforation of the intestines, of which 2 were of the small intestine. Gosset concludes in favour of operation, if it can be performed early and carried out under good conditions and followed by sufficient care. In operating on the wounded "we shall heal a certain number, if we are mindful not to operate on those whose lesions appear *a priori* (for instance, those wounded by shells) beyond our resources."

The laparotomies of Vertraeghe [*], analysed by M. Tuffier on April 28th, afford the special interest of having been carried out from half an hour to six hours after the wound was received, and close to the firing-line. Eight failures first resulted, due chiefly to the extreme gravity of the lesions. Of the three successes that followed, one concerned a perforation of the small intestine. On this occasion Tuffier declared: "I do not believe there actually exist, among all the wounded of the French Army, twenty recoveries from wounds of the small intestine treated by laparotomy and sutures. In spite of these failures, we must persevere in operative treatment whenever the surgeon, the installation, and the case afford reason to hope for a favourable result"; and Tuffier gives us to understand that he considers these conditions are rarely realised or realisable.

To sum up, taking into account the communications that we have noticed in the course of the first

period, the following are the opinions expressed so far at the Chirurgical Society regarding the use of laparotomy in the treatment of abdominal wounds caused by war projectiles :

Those with a definitely antagonistic attitude are MM. Sencert, Weiss and Gross, Cadenat (reported by Hartmann), and Devèze (reported by Tuffier) ; the three first are abstentionists, the last is an advocate of the supra-pubic button-hole. Those in favour of operation are MM. Duport and Kendirdjy, with very few documents (reported by Baudet), Hallopeau with very few documents (reported by Routier), and finally Gosset. Chavannaz, a little wavering, leans to the side of intervention. Tuffier remains undecided.

Here Quénu enters the arena, and his influence promises to be continuous and decisive. In four fundamental reports, he sets forth a number of increasingly numerous case-reports, and brings to their analysis a rigour and impartiality that inspire conviction ; during his exhaustive study of penetrating wounds of the abdomen he produces at every stage new arguments in favour of laparotomy. Encouraged by the moral weight of his renowned sagacity and of his long experience, the young surgeons in the first line undertake with more confidence and ardour an operation hitherto officially discredited, and events soon begin to justify the master. It is no exaggeration to say that if laparotomy has saved many and many a man who would otherwise have been irremediably condemned, if the surgeons have adopted it and if the military authorities have been led to perfect the equipment which allows of its general practice, it is to the utterances and the tenacity of Quénu that this revolution is due.

The first of his reports is dated June 16, 1915 ; it is supported by 19 cases observed by Schwartz, 9 of which were laparotomies, and 33 observed by

Bouvier and Caudrelier, all with systematic laparotomy. The 9 cases operated on by Schwartz included 8 with perforations of the small intestine; 1 with perforations of the spleen and wounds of the mesc-colon and the great omentum; there were two complete recoveries, 2 operative recoveries, and 5 failures. In comparison with these results, 10 cases treated by abstention resulted in 7 deaths; the 3 recovering were in no way concerned with lesion of the small intestine, 2 of them being wounds in the lower part of the abdomen, and 1 being an uncertain wound in the left iliac colon. Schwartz concludes in favour of laparotomy.

But the essential basis of Quénu's report consists of the observations of Bouvier and Caudrelier [13]; their number is the most considerable hitherto met with. Laparotomy was systematically practised on all the wounds, whatever the gravity of their condition; most often it was a question of wounds caused by the explosion of shells or bombs; the surgeons operated quite close to the front, in an advanced post, specially fitted up for abdominal operations of extreme urgency; and the number of recoveries was not less than 15 in 33 cases (45 per cent.). Starting from these observations, Quénu studies successively—the nature of the projectile, the interval elapsing between the wound and the operation, the condition of the wounded at the time of the operation, the nature of the lesions observed, the surgical method adopted, and lastly the results. He then makes a recapitulation and retrospective criticism of all the previous communications, sifts the recoveries attributed to expectant treatment, and shows that their number must be considerably restricted if only penetrating wounds or those with certain visceral lesions are considered, and concludes finally that "laparotomy is the best form of treatment, and the one giving the best results, provided that the operation is performed under certain condi-

tions of promptitude (which are not always realisable), of installation and of operative technique, of post-operative attention and subsequent discharge from hospital."

A complementary case—report by Goinard, Poiret and Roland [15], quoted by Quénu at the same meeting, concerns a wound with intestinal perforations and multiple vascular sections. Laparotomy was followed by recovery.

On September 22nd Quénu made a *second report*, including two observations by Petit [17], 47 by Bichat, 15 by Pascalis, 24 by Pellot, lastly and chiefly 66 new laparotomies by Bouvier and Caudrelier, forming a collection of 153 cases, among which are 110 operative interventions, of which 6 are Murphy's operations, 1 secondary laparotomy, and 103 primary laparotomies. In the first part of his paper Quénu gives a critical analysis of each particular case. We will content ourselves with recording that Bichat [16], originally a partisan of abstention, comes at length to practise laparotomy systematically, as does also Pascalis [18]. On the other hand, Pellot [20] attributes genuine and numerous successes to operative abstention; he limits the indications of laparotomy to very serious hæmorrhages, and to omental or intestinal hernias. Apart from these cases, it is a question of "armed expectation," classified in the following manner: (*a*) Small projectile: intervene only if the state of the patient becomes aggravated, and then make, preferably under cocaine, an intestinal suture or an arterial ligature; if the wounded man is too weak for this, use the median button-hole, lavage by ether or drainage, adding, if the liquid is not clear, lateral incisions for drainage. (*b*) Large projectile; abstain if the colon is involved; but if it is the umbilical or periumbilical region that is concerned, operate; "for as a rule these patients are doomed to die." It is obvious that these conclusions are not shared by the reporter. The

cases reported by Bouvier and Caudrelier [21], still more numerous than in their first communication, retain the same reasons for special interest, with a still better proportion of successes—54 per cent. From all the case-reports thus collected together the reporter eliminates the non-penetrating wounds; he thus obtains a total of 96 penetrating abdominal wounds treated by laparotomy, with 53 deaths (55 per cent.), and, of these 96 wounds, in 60 cases the intestine was involved. Now the preceding report gave a mortality of 67 per cent. for abstention, and this figure is abnormally favourable, for the cases are numerous in which one believes oneself justified in clinically affirming penetration, when in fact neither the peritoneum nor the intestine has been attacked. Quénu then handles the following secondary questions: the indications for operation; the conditions in which one should operate to have the best chance of success; operative technique; post-operative attention, including the discharge of the wounded.

Quénu's *third report* to the Chirurgical Society was made on November 24th, 1915. Forty-six are cases credited to Schwartz and Mocquot, and 26 to Mathieu, making a total of 72. The exceptional gravity of the lesions encountered by Mathieu [25] explains the high rate of mortality, 77 per cent. As to the results obtained by Schwartz and Mocquot [24], they prove that they have saved by laparotomy a certain number of wounded who, without their intervention, would have died (total mortality of 60 per cent.). "Could they, in other conditions, have saved a greater number? It is probable, if they had had the wounded a little earlier . . . it ought to be possible to make progress in this respect." The reflections of the reporter are therefore centred on the conditions of collection, transport, and overcrowding: "The improvement in the results does not depend only on the efforts of the surgeons, but on the co-operation of those in command

and those in charge of the organisation of the service de Santé."

Although it is later in date than several important works that we shall find later on (notably Rochard's report and the sensational communication of Chevassu) we shall here quote Quénu's *fourth report*, as it completes and is intimately connected with the three preceding ones; and this conjunction renders still more emphatic the importance that should be attributed to the energetic campaign carried on by Quénu. At the meeting of January 5th, 1916, he successively passes in review: a note by Rouhier [28] on the urgency of the localisation of abdominal projectiles and its utility in the choice of operative indications; 26 cases of penetrating wounds coming from Barbet and Bouvet [29]; from which one may conclude that the results will be better "if one does not take such extreme care not to open the abdomen for a non-penetrating wound." Twenty case-reports by Didier [30] must, after discussion, be classified in this way: 10 laparotomies, 4 recoveries; 7 Murphy operations, 2 recoveries; 3 abstentions, 3 recoveries (wounds of the upper abdomen and the flanks). Didier declares himself convinced of the superiority of laparotomy, if it can be performed very soon, and if the operative installation is adequate. Gatelier's 23 cases have the experimental value of opposing two comparable series: thus, 12 wounded treated by abstention all died; and, of 11 laparotomies, 5 recovered (mortality 54 per cent.). These observations lead to the writer's reflections on anæsthetics (he inclines to chloroform) and on thoraco-abdominal wounds, certain of which ought be treated by abstention.

This concludes a first series of studies by Quénu with which is connected a communication to the Academy of Medicine of October 26th, 1915 [31]. They form the most convincing argument, and a most eloquent one by virtue of the facts, completely in favour

of laparotomy. (Still later Quenu intervenes again in its defence, but that occurs in the course of what we have called, in our classification, the third period.)

There are other communications to the *Chirurgical Society* that deserve to be quoted.

Chaput [15] is of opinion that, to be just with regard to laparotomy, the following should be eliminated from the statistics: wounds with numerous intestinal lesions and large mesenteric wounds, which are almost fatally doomed (one recalls here that it is to these cases Sencert would confine the imperative indication of a laparotomy certain not to be harmful) the cases in which the wounded died some hours after the operation; late operations performed after twenty hours of violent peritonitis. Statistics do not possess their full value unless they include wounds of moderate gravity.

Tartois [11], returning from the first Balkan War an adherent of the principle of surgical abstention, repudiates it to become the champion of a rational surgical intervention—that is to say, as complete as possible by including laparotomy. Duval's report brings out all the interest offered in the 34 observations of Tartois by arranging them in three series: 8 abstentions are followed by 8 deaths; 15 Murphy operations produce three recoveries (a mortality of 80 per cent.); and 11 laparotomies procure 5 recoveries (mortality 55 per cent.). A comparison which speaks eloquently for itself.

In an "Essay on Operative Indications in the Zone of the Armies," analysed by Quénu on July 21st, Heitz-Boyer [16] had incidentally touched on wounds of the abdomen. Influenced by the opinions of Sencert, he insists that "the indications for operation are found to be dominated by the equipment question"; primary laparotomy appears to him more and more susceptible of being put in practice, but only if new operative formations realise the necessary

conditions. Again, he remarks that the "relative rarity of these wounds should deter us from according them a disproportionate importance; in any case, they could not demand a special organisation for their treatment." Quénu is less readily resigned than Heitz-Boyer; laparotomy is the preferable treatment; it should be rendered practicable; an organisation is to be condemned "which would sacrifice deliberately 3, 4, or 5 wounded out of 300." Thus, at every opportunity, Quénu defends his favourite thesis.

Analysing a monograph of Stern's [17] concerning 143 abdominal wounds of which 34 were treated by laparotomy, with 14 recoveries, Rochard showed a not less decided conviction. From the outset he does not conceal his determined opinion. "Logic," he declares, "has triumphed over paradox: penetrating wounds of the abdomen caused by the projectiles used in war at last enter the domain of active surgery. And what a solace to our understanding! Our minds found a difficulty in admitting that what had been verified before the war, and what will no doubt be verified when the war is over, could suddenly become an error in the course of it. . . ." Rochard, in his turn, undertakes to prove that "laparotomy ought to be applied to war-wounds as well as to civil wounds." In this study, in which the method and the pains he takes to be thorough yield in no way to Quénu's, he proposes a new classification of the lesions, rather different from that of the preceding authors. (He eliminates from abdominal wounds those which are purely parietal; to which Quénu objects that very often under clinical conditions and in the choice of a decision as to operation, it is very difficult to distinguish accurately penetrating from non-penetrating wounds. He also separates exclusively abdominal wounds from associated abdominal wounds.) Clinical diagnosis, operative indications, operative counter-indications (state of the wounded, external

circumstances, age of the wound), the choice of operation, operative technique, post-operative care, anatomo-pathological findings and results, receive separate consideration. Rochard ends with some general statistics of all the cases published up to that date by the Chirurgical Society, which show that in 266 laparotomies there were 161 deaths, a mortality of 60 per cent.; in 322 cases not operated on, 258 deaths, or a mortality of 80 per cent. Thus the best treatment still appears to be that of early operation.

We would also notice a communication from Abadie [33] dated March 1st, 1916. He studies successively the treatment to be preferred, the practical conditions of its application, and the means for rendering these conditions most often realisable. It would be superfluous for us to dwell longer on this contribution, as it is inspired by the same ideas as those we are elucidating, and reflects the same mode of discussion. We will content ourselves with recording that 15 laparotomies resulted in 6 recoveries.

Lastly, we have the comprehensive study by Rouvillois [34] of March 22nd, 1916. Having observed 247 abdominal wounds, Rouvillois reports 132 cases, and arrives at the following conclusions: abstention in undoubted peritoneal wounds gave him 89·5 per cent. mortality, and, if he added to this the deaths which would have been sure to take place among cases operated on who recovered, it would make the total very nearly 100 per cent. Murphy's operation gave him a mortality of 82·1 per cent. Close analysis of these facts would bring a total of as much as 100 per cent.; in any case, he considers Murphy only a last resource; laparotomy (74 cases with 20 cures) represents a mortality of 73 per cent., and is incontestably the preferable treatment; thoraco-abdominal wounds should be treated by abstention; laparotomy results in 100 per cent. of mortality. These conclusions are preceded by a very detailed exposition of the lesions

and symptoms observed, with a discussion on diagnosis and indication of technical details.

This work concludes the series of memoirs sent to the Chirurgical Society, which, however late the date of their appearance, are all inspired by the same tendency. They ought also to be grouped in the second period, with the four fundamental reports by Quénu.

It is the same with other studies that appeared outside the Chirurgical Society. Everywhere laparotomy is gaining ground.

Leriche [42] showed "the necessity for systematic operation in wounds of the abdomen." Laparotomy alone would diminish to an appreciable degree their frightful mortality. The author notes that in 117 cases observed by him, in which an operation did not take place, the mortality was 89 per cent.; he only knew of two interventions, made in very precarious conditions, yet both were crowned with success.

Delore [43] is still more severe with regard to abstention; in over 100 cases not operated on, not one recovered. He proves, by examples, the remote dangers of abstention (subphrenic, "Douglas" abscess (in recto-vesical pouch) and chronic peritonitis). On the other hand, he supports by some typical facts his warm advocacy of laparotomy "whenever surrounding conditions are not against it."

Cotte and Latarjet [44] arrive at the same conclusions. Their article includes anatomical observations very carefully drawn up, with photographs of characteristic lesions. We note that seven laparotomies afforded them four successes.

Murard [45] is of quite a different opinion; he distinguishes "closed abdomens" from "open abdomens." For the first, laparotomy is dangerous and inefficacious; Murphy's button-hole, on the contrary, has the great advantage of being simple, safe, and of being "sometimes" useful. For the second, surgical intervention

is only successful if it is used in simple omental hernia ! That is not saying much.

According to Tisserand [47] nearly all, if not all, "true abdominals" succumb if they are not operated on ; Murphy's operation is insufficient in serious cases, and useless in slight ones ; laparotomy alone is the rational treatment, and special surgical posts ought to be multiplied in the immediate neighbourhood of the front.

Vignard [48] counsels moderation. Although he takes his stand by the side of the interventionists, he shows by 20 observations that the *cacoëthes secandi* should not dominate the spirit of observation and criticism without discussion.

Chalier [49] is eclectic. Fifteen abdominal penetrations, certain of them treated medically, resulted in 4 deaths ; but the 11 cases healed included 5 ureterorenal wounds, 1 vesical wound, 3 wounds of the liver, 2 wounds of the large intestine, *none in the small intestine.* Fifteen probably penetrating wounds recovered. Nineteen cases treated operatively included : 2 incisions in encysted purulent collections, 2 recoveries ; 12 Murphy operations, 10 deaths ; 3 lateral buttonholes, 1 recovery ; 2 laparotomies, 2 deaths. Chalier concludes by condemning Murphy's operation. In spite of his personal want of success, he inclines to favour early systematic laparotomy "if the material conditions permit of it."

In a month of abdominal surgery at the front in an advanced post similar to that in which Bouvier and Caudrelier operated, Delay and Lucas-Championnière [50] practised 22 laparotomies with 11 recoveries (mortality 50 per cent.). It is to be noted that in 10 cases in which there were multiple wounds of the small intestine, there were nevertheless 4 recoveries. These two authors evidently range themselves in the camp of the interventionists, and advise laparotomy whenever there can be united "a wounded man in the third or fourth hour after he receives his wound, an instal-

lation affording every guarantee of asepsis, and a staff of surgeons and assistants, reduced it may be, but keen and *specialised.*"

In the medico-chirurgical meetings of the different armies, it was inevitable that the healing of abdominal wounds should many times form the subject of discussion. Gaudier [53]—6th Army—in 75 cases not operated on had only 3 recoveries; he considers that Murphy's operation may transform acute into chronic peritonitis, but hardly ever prevents death, quite the contrary—and these figures are truly interesting—a first series of 9 laparotomies gives 4 failures; but a second series of 5 gives only 1 failure. Gaudier insists that laparotomy must take place very quickly.

In the 4th Army, Pellot [54] obtained 32 per cent. of recoveries by operating. Mocquot denounces abstention, and relates the results that we have seen communicated by him, in conjunction with Schwartz, to the Chirurgical Society. Vouzelle is convinced that, in time of war, more even than in time of peace, intervention should be had recourse to, and that for two reasons: the first is the great seriousness of the wounds, due in most cases to the explosion of shells; the second, on which he insists, is the frequency of fatal hæmorrhages. Bréchot reports two cases of fatal peritoneal complications developing late in wounded men who had not undergone laparotomy. Potherat considers that there ought not to be interventionist and non-interventionist surgeons; with abdominal, as with all other wounds, it is not admissible to decide *à priori*. In his opinion, there are cases in which it is impossible to abstain from intervention—in hernias of the intestine or of the omentum, in hæmorrhages of the liver, the spleen, and the intestinal arteries, which are so frequent and so critical. There are, on the other hand, wounds where abstention is to be recommended: in those confined to the colon, or involving the stomach. Regarding wounds in the region of the small

intestine, intervention is doubtful. It is fully justified if one can intervene in the first twelve hours, and when the state of shock is not too marked; otherwise it is better to abstain. Séjournet presents ten unpublished observations, with three recoveries; in four of the cases followed by death the lesions were extremely serious.

Clermont [56]—10th Army—operated on 1 simple penetrating wound (1 recovery); 11 univisceral wounds (6 recoveries); 6 multivisceral wounds (6 deaths). The whole mortality is, therefore, 61 per cent. A communication by Gorse [5] has the exceptional merit of defending Murphy's operation, which we have so far seen more and more discredited. Gorse has obtained 4 recoveries in 15 cases; in each case it was a question of a bullet-wound.

The second period marks the triumph of laparotomy.

. . . . . .

Third Period.—Things were at this stage when on November 17th, 1915, Chevassu [35] read to the Chirurgical Society a "Study of 210 Cases of Abdominal Wounds observed in a Fifteen Days' Offensive in a Surgical Automobile Ambulance, and especially of the Good Results of Abstentionist Methods." All the terms of this title deserve attention: the large number of cases observed by the same author; the sustained offensive, replacing the momentary combats of the trenches; the automobile surgical ambulance—that is to say, a surgical installation realising the most perfect conditions of operative surroundings then possible; lastly, the title, which does not hide, but rather takes pains to inform us, that the results are favourable to abstention. If we take into account, besides, the rank and also the scientific position of the author, we can imagine the sensation his communication must have caused, and the trouble it must have produced in the minds of those who seek only facts that shall strengthen their convictions.

Tuffier's report [35] on Chevassu's Study only appeared on March 15th; this explains the number of works appearing in the interval that merited classification in the second period.

The following are the figures of Chevassu's memoir: in 210 abdominal wounds observed, he includes 136 peritoneal wounds with 53 deaths and 79 discharges from hospital. These 136 cases are further divided thus: 41 operations, 27 deaths; 91 abstentions, 27 deaths; 4 deferred operations, 3 deaths. Thus, in striking terms, we have a mortality of 65 per cent. with abstention. Is it astonishing that Chevassu, hitherto an interventionist, rendered an abstentionist only by necessity, should now become an abstentionist by conviction? For if these figures are rigorously established and indisputable, if the abdominal wounds (even the intestinal ones) heal by themselves better than after operation, it is evident that intervention is useless. Nothing remains but to resist "the old surgical instinct that springs up, and to allow the abdominal wounds to evolve in their own way."

Only—and here is the delicate point—these figures must be carefully scrutinised. Tuffier is the first to criticise them. To begin with, he only admits as valid 100, in which penetration was positive; they gave 53 deaths; but, as 15 of the wounded died almost immediately, before treatment, only 85 cases should be retained, with 38 deaths, or a 44·7 per cent. mortality; in the 36 remaining cases, where the lesion of viscera is only a probability, 4 deaths give a mortality of 11·11 per cent. If we only retain the coefficient of 44·7 per cent., it still remains very small and impressive. When this is done, Tuffier classifies the cases successively according to the organ attacked, and compares, in each series, the coefficient of mortality obtained in all the cases operated on which had been published up to that time with the coefficients obtained by Chevassu, whether by operation or by abstention; such a com-

parison must evidently be very instructive. We represent it in tabular form.

—	Chevassu: Abstention.		Previous cases: Operations.		Chevassu: Operation.	
	Cases.	Mortality.	Cases.	Mortality.	Cases.	Mortality.
		%		%		%
Eviscerations: intest.	3	100	26	76·92	7	75
omental	2	50	32	62·5	3	66·66
Stomach . . .	9	0	25	64	1	100
Liver . . .	11	18·18	70	54·28	5	80
Kidney . . .	12	25	20	65	2	50
Spleen . . .	1	100	21	85·7	—	—
Large intestine . .	2	0	—	?	5	40
Small intestine . .	32	18·75	185	72·45	8	62·5

We see that for all the lesions, except for intestinal hernias and serious wounds, the coefficient of mortality obtained by Chevassu with abstention is very notably lower than that given by operation.* The only lesions that demand attention are *wounds of the small intestine*. Chevassu presents 40 of these cases, of which 8 were operated on, with 5 deaths; 32 were not operated on, and 6 deaths resulted. Now Tuffier, after criticism of the case-reports, retains only 28 in which peritoneal penetration is certain, and only 10 in which the small intestine was certainly injured; and these 10 cases give 5 deaths. Thus the mortality of 18·75 obtained by Chevassu now amounts to 50 per cent.! But it still remains stupefying, altogether out of proportion to anything that had been established since the commencement of the war!

Besides that, it cannot but be somewhat disappointing for the laparotomists to find that one single abstentionist has, without any trouble, obtained 26 recoveries from intestinal wounds, while, according to Tuffier, up to that time only 31 recoveries had been with difficulty

* It is to be noted that three Murphy operations gave three deaths.

brought about by the successive efforts of numerous operators!

The conclusions of the reporter may be summed up as follows: "The figures of M. Chevassu are striking, but they are insufficient for judging of the matter; they demand new documents to establish them, and our conduct since the commencement of hostilities is justified." And in conclusion he adds: "Laparotomy aggravates the prognosis very slightly whenever the state of the wounded, the material organisation, and the experience of the surgeon permit of its execution."

Conclusions so reserved and so exceedingly prudent only aggravated the sensation produced by Chevassu's memoir; they certainly justified retaliation on the part of Quénu, and his new defence of laparotomy. "The communication of M. Chevassu," he declares, "is pregnant with dangerous consequences and contrary to surgical truth, hence I conclude that it is my duty to complete in a clear and categorical manner the work of the case-reporter." Ought one to operate on the wounded, or leave them to the healing of nature? This is, again, the burning question. Take, in the first place, the *wounds of the small intestine.* From 40, Tuffier has reduced the number to 10, with 5 recoveries. But we have also to eliminate a wound of the stomach and not of the small intestine, and a wound with an uncertain intestinal lesion. Of these 8 wounded, only 2 recovered, giving 75 per cent. mortality, and—another very interesting fact—these two single recoveries from undoubted wounds of the small intestine were cases of bullet-wounds, in which the wound of the intestine was situated opposite the parietal wound: the intestine therefore could evacuate its contents outside, instead of pouring it into the abdomen. Figures so greatly reduced retain no interest as to the coefficients of recovery or death. On the other hand, the reduction to 31 of the total number of recoveries obtained

by the laparotomists cannot be admitted. Quénu redresses the balance: he gives 64; here we have 64 wounded men all, or nearly all, snatched from death by operation!

Similar criticism is made as to the wounds of the large intestine, the stomach, the kidneys, and the liver; the indeterminate peritoneal wounds, particularly, present 16 deaths for 16 cases!

And Quénu again confirms what he has always maintained: "The non-punctiform perforations of the small intestine can only heal by being stopped up; and with regard to the punctiform ones, they represent the really favourable cases, and those which most surely benefit by intervention."

The therapeutic indications, therefore, remain as before.

Chevassu's communication had incited Marquis [25] to enter the debate with the figures furnished him by abstention, which he had adopted primarily by conviction, but also by necessity during the battle of the Marne. Of 68 abdominal wounds (among which an indefinite number were non-penetrating) 32 recovered (21 being bullet-wounds).

The desire to react against the mischievous influence of Chevassu's communication can be perceived in the view of "Evolution" given by R. Picqué [34], writing of the treatment of abdominal wounds in his ambulance at the front. It is nothing less than a very complete study of the question, starting with operative indications, as they concern the surroundings, and the wounded, and going on to the technique, with useful reflections by the way on the "para-peritoneal syndrome" and the radioscope. But we may definitely gather from it that "having been at first an interventionist, and going through an attack of voluntary abstention, he again finds himself a resolute interventionist."

Can we wonder? Sixteen cases of abstention yielded him 2 recoveries; 14 palliative operations, 14 deaths;

15 laparotomies, 6 recoveries. From these statistics we again observe the rarity of spontaneous healing, the failure of palliative operations, the absolute harmlessness of laparotomy and its encouraging results, which the future will only accentuate. But, to improve these results, certain ambulances must be specialised for surgery, and even for the treatment of those grievously wounded. And progress in this direction, writes Picqué, "should put an end for ever to the hindrance of overcrowding, as well as of surroundings." A valuable declaration, considering its origin.

The same opinion is expressed by Grégoire [67]: "Can we under present conditions operate on abdominal wounds at the moment of a great offensive? Decidedly, no!" he replies. But there are means of avoiding the overcrowding. Certain ambulances must be specialised and confined to these wounds; special automobile carriages must be designed for the transport of those wounded in the abdomen; the surgical installations must be placed as near as possible to the fighting-line and on the most accessible route; the surgeons must be able to watch, to look after, and to follow their wounded until they are out of danger.

Agreed, but . . . that is just where the difficulty lies.

Twenty new laparotomies by Simonin [68] are the object of a supplementary report by Quénu, April 12th; they afford a total mortality of 60 per cent. Here, again, stands out the difference of gravity between univisceral wounds (mortality 60 per cent.) and the multivisceral (mortality 100 per cent.). Reflections follow on the often invincible difficulty in the diagnosis of penetration or non-penetration, and on the necessity of specialised units, since the others will be overwhelmed by the influx of wounded, etc.

Forty-six observations by Rouhier [69] serve as a point of departure for Pozzi to make, in an attractive paper, another study of the question which interests us, in which, incidentally, his personal experience con-

firms practical advice; we note specially the views on "trophic shock." In 15 laparotomies for really penetrating wounds Rouhier obtained 6 recoveries (mortality 40 per cent.); of this number 12 operations were for intestinal wounds, and gave 3 recoveries (25 per cent.).

In the meanwhile Pauchet [7], investigating the best method for reaching the organs in relation with the lesser sac of the peritoneum, and notably the posterior surface of the stomach, advises the incision of the gastro-colic omentum; he heightens the clearness of his description by eight demonstrative figures.

Here, as characteristic of the actual state of the question, we must report the conclusions that terminated the discussion, sometimes a very lively one, which took place at the Chirurgical Society. Quénu had already written, when criticising Tuffier's report on Chevassu's communication: "Absence of organisation or bad organisation should not be allowed any weight in falsifying therapeutic indications. There is no lack of resources either in material or in men—we have only to utilise them. Do we always do so?"

In a lively meeting on May 10th, Pierre Delbet, Souligoux, Rochard, Monprofit and Broca intervened in turn to oppose the "restrictions" with which Tuffier was reproached, and his lukewarmness with respect to intervention; but, above all, to demand anew a better material organisation and a more judicious use of the means at disposal. And the following resolution was unanimously adopted:

"The Chirurgical Society pronounces in favour of early intervention in cases of wounds of the abdomen. It also gives utterance to the desire that, to ensure attention to these cases, and to all others severely wounded, where the rapidity of the operation has great influence on its success, motor ambulances should be concentrated as required, and for the necessary period,

at the spot where the wounded arrive in greatest numbers."

At this point our historical record stops.

. . . . . .

We can now summarise, in a few lines, the three periods in which we have seen the *evolution of the treatment of abdominal wounds* develop during the present war.

During the first period, under the influence of previous wars, as we find it expressed in administrative circulars, abstention is the rule; the only operation allowed is the supra-pubic button-hole. The results obtained by either of these methods are gradually found to be disappointing.

In the course of the second period, dominated entirely by the influence of Quénu, at once combative and encouraging, laparotomy multiplies its successes and increases the number of its partisans.

A third period sees the development of a reaction in favour of abstention, not as the method to be preferred, but as the method of necessity affording numerous successful results. But these successes are contested, and often appear illusory as regards genuine penetrating wounds with visceral lesions.

We have also seen that these three periods correspond with three different modes of strategy, which necessitate special conditions of *operative surroundings*.

First came a period when the armies were incessantly in motion, when there were battles of great importance, and the surgical organisation was defective.

Then followed a time of stationary armies, of trench warfare, of improvement in transport and surgical equipment and hospital provision. Two types of specialised organisations came into being: surgical automobile ambulances and advanced surgical posts close to the front.

A return to the war of offensive conflicts in great

masses shows that these organisations are insufficient. Is this inevitable ? May we not hope for better things from an organisation more supple and more judicious in the use of the means at its disposal ?

Another parallel may be drawn as regards the *nature of the projectiles* most frequently encountered.

During the first period the projectiles were bullets, and the greater part of the wounds healed by abstention were produced by them.

In the second period trench mortars and shells came into play. Abstention was shown to be inefficacious, and laparotomy proved itself the only therapeutic resource of any value.

In September 1915 numerous bullet-wounds were again observed, and abstention again asserts itself as a means of healing.

All these facts are data which will prove their utility when the time comes to discuss what is the treatment to be preferred in penetrating wounds of the abdomen.

CHAPTER IV

ANATOMICAL LESIONS

CAUSES, FREQUENCY, GRAVITY, AND THERAPEUTIC CONSEQUENCES

IT is not a question here of describing, organ by organ and degree by degree, the different lesions that the wounds of war may cause in the abdomen.

The important matter is to indicate details which may help :

(1) To realise the anatomical possibilities of the spontaneous healing of the lesions, and consequently the limits in which one may reasonably count on a salutary effect from simple abstention.

(2) To support the necessity for direct surgical intervention, and to show that it is necessary in the majority of cases ; we shall see, also, that certain lesions too often remain beyond the resources of even the most expert operative action.

(3) To specify the details of technique.

It is under these different aspects that the lesions have an immediate interest for us in practice.*

* As we proceed, we shall support our statements by statistical figures. They have been obtained from the totals of the case-reports hitherto published, so far as we are acquainted with them. We have thus sought to obtain coefficients more exact, as representing a larger number of facts. (See the recapitulative table on p. 396). In the case of anatomical lesions it is obvious that only autopsies or exploratory operations are taken into consideration. In general we rely on the latter.

But one great primary idea must be borne in mind, that of:

The Influence of the Nature of the Projectile on the Form and Gravity of the Lesions

In former wars only wounds from side-arms, bullets, and sometimes from shrapnel were met with, and had to be reckoned with from the surgical point of view. There was no question of the wounds caused by the bursting of shells. It is a sad privilege of the present war that we have beheld the appearance and the increase in importance, even to the point of eclipsing all the others, of wounds caused by the bursting of percussion shells, and by trench machines (grenades, bombs, mortars, etc.). And we shall see that these are precisely the most serious.

Wounds from side-arms are absolutely exceptional. I do not think that a single case of *sabre-wound* has been published. That is easily explained. The cavalry has hardly intervened, and then only at the beginning of the war, except for reconnaissances: single combats are the exception, it being the carbine or the rifle that plays the part of offensive or defensive weapon at long range: the group of combatants is already destroyed, or surrounded and forced to lay down its arms, before the sabre can be brought into play. Cavalry charges almost seem to belong to another age, and the sabre has made and will make hardly any victims.

The *bayonet* is still frequently mentioned; it is possible that "Rosalie" may frequently be a cause of wounds on the opposite side of the lines: but wounds from German bayonets are rare with us (personally I have only seen three cases in 3,500 wounded): wounds of the abdomen caused by them are rarer still. A few instances are mentioned by Picqué, and by Petit.

Picqué [14] has observed and operated on three bayonet-wounds, with two recoveries. One was a case of double perforation of the transverse colon and

free stercoral effusion into the left paramesenteric fossa. This resulted in recovery. The second had puncture of the left kidney and submesenteric hæmatoma—this also resulted in recovery. The third, with double perforation of the sigmoid flexure, died.

Petit's case was due to an accident (wound of the liver with very great hæmorrhage).

Besides, the bayonet is habitually wielded with such violence and so unmercifully that wounds made by it are usually fatal.

It is the same with the *trench knife*, and to any one who is acquainted with its form and the manner of use of this instrument, so typical of a war without mercy, it is evident that when it is handled by a "cleaner-up of trenches" it will leave little room for the appearance in an ambulance or on an operating-table of a man with a knife-wound in the abdomen.

The modern *bullet* might seem to have humanitarian qualities owing to its small calibre, but its speed of propulsion and rotation, the living force with which it encounters all obstacles modify, and generally amplify, the presumably small size of its track. Although the part played by detached splinters as independent projectiles cannot be gone into here, we know that the abdominal viscera are very diversely injured according as the bullet arrives from a point close at hand, in full course, medium course, or at the end of its course.

When the shot is a close one, the bullet makes great havoc in the abdomen by its "explosive effect." This is easily explicable in the region of the solid viscera, like the liver, the spleen, or the kidneys, and we shall consider these effects later on; but it also acts in the region of the stomach and the small intestine, especially if these viscera are not empty, as during the process of digestion. Although occurring on a smaller scale, being more limited, and acting simply on richly vascularised intestinal regions, where the pro-

portion of fluid traversing the tissues is large, the "burst" still produces an effect; it makes orifices out of all proportion to the calibre of the bullet; it rends and detaches; it occasions mesenteric separation by mediate action, not by direct tearing. And these serious lesions are principally met with in the bullet-wounds of trench warfare and fights at close quarters.

Here is one of the most typical examples from many others:

"D—— was hit on March 1st, 1915, by a bullet coming from a short distance. The wound of entrance on the left flank was punctiform: the wound of exit on the right flank was as large as the palm of the hand; blood was flowing from it in abundance. The shock was intense. The pulse was imperceptible. Immediate laparotomy (in the third hour) showed the abdomen full of blood and fæces. I closed five perforations of the small intestine, and then found three coils entirely divided at several points, extensive mesenteric separation, fragments of the small intestine floating about in the mixture of blood and intestinal contents. Nothing could be attempted. We had to close up the wound. The patient died two hours later." (Abadie [33]. Obs. 5.)

When the abdomen is hit by a bullet in full course, at a moderate distance, say 200 metres, the most favourable conditions exist: the ball goes right through, making very narrow parietal openings, and intestinal punching perforations or intra-parenchymatous tunnels.

When the bullet is at the end of its course it may remain in the abdominal cavity, for instance in a solid viscus (this happens most frequently in the liver); cases have even been observed where the bullet has remained loose in the peritoneal cavity, having traversed the abdominal wall without causing any visceral lesions (Quénu [71]).

When a projectile strikes by *ricochet*, the gravity of the lesions is at once increased, and this fact is specially noticeable as regards bullets, as the contrast is greater in them than in any other projectile between their ballistic properties before and after. Instead of a penetrating movement around its axis with regular rotation, the bullet is projected according to an unaccountable trajectory, oblique or curved, and above all it seems to be animated by a movement of rotation around some chance point of its substance; becoming "mad," it attacks the body at some uncertain incidence, presenting itself by the point, the side, or the bottom, and continuing in the tissues its erratic gyration. This gives rise to considerable damage.

Shrapnel bullets, of hardened lead, in the form of a billiard-ball, or part of a billiard-ball, have generally a feeble penetrating force. They hardly ever entirely traverse the body. Some have even been extracted that had stopped in the peritoneal cavity and remained encysted in the omentum (see Figs. 1 and 2 and Walther [69]). The injuries they produce are local, without bursting or irradiations, but they have the great drawback of bringing into the wound septic fragments of clothing. Though almost the only cause of wounds due to artillery during the wars of Manchuria and the Balkans, and still frequent at the commencement of the present war, they are becoming rarer as the use of percussion shells becomes more general, and since these latter are not confined to the destruc-

FIG. 1.—Shrapnel-ball encysted in the omentum. Gouillioud and Arcelin [75].

tion of buildings, but are liberally employed against the troops themselves.

Revolver-bullets are rarely met with. They are chiefly found in accidental wounds caused by imprudence. Nothing remarkable is discovered as to their gravity which was not known in time of peace. We may observe, however, that they are bullets of large calibre (8mm. or 7·5 mm.), and of great initial swiftness.

FIG. 2.—Shrapnel bullet encysted in the omentum. Torsion of the pedicle. Gouillioud and Arcelin [75].

Fragments of shells are now found to be the usual cause of the wounds we meet with. Their size is very variable, ranging from that of a grain of corn to a large thumb, but their surface is always rough, with sharp angles, finely jagged or fringed (Figs. 19 and 46), and they are possessed of a force of penetration that varies according to the distance at which the shell has burst. Their lesions are rendered much more harmful in that they nearly always drag in with them pieces of clothing, and the septic nature of these pieces aggravates the infections caused by the contents of the abdominal viscera. One has even observed cases in which the entry of fragments of this sort through the abdominal muscles has accounted for the separation of the edges of a laparotomy or the suppuration of the edges of the traumatic wound, or even the appearance of gas gangrene in the abdominal wall. We have ourselves observed two instances of this. (See pp. 495 and 517)

The splinters of grenades, bombs, shells from mortars and minenwerfers, in short, the effects of the engines of the trenches, are equally to be dreaded. Their form is infinitely varied: fragments of iron wire drawn to a point, chips of tin fringed or bent back into little grooves, etc. (Figs. 17 and 53.) There is a *surprising disproportion between their size, their very small weight, and the extent of the muscular, parietal, or visceral lesions that they occasion.* Just as we often see a minute particle form a veritable cavern in an osseous epiphysis or in a bone of the tarsus, so we see the projectile form round itself, in a solid viscus, a vast cavity of irreparably damaged tissue. The force of penetration due to the almost invariable nearness of the explosion is aggravated by a mad rotation of the projectile. The segments of spherical cast-iron grenades, comparable to "soft caramels" as to form, are generally less dangerous. All these different fragments bring in textile particles: it would seem also that certain of them have a necrotic effect, due to the chemical substances with which their parts had been in contact. And what still more increases the gravity of the wounds caused by the trench mortars is the multiplicity of wounds, which in some cases become innumerable and disseminated over the whole body. The danger is greater when an abdominal wound is found to be accompanied by penetrating thoracic lesions, or when the number of the wounds in the limbs considerably aggravates the shock.

The *little arrows* of the air-men have gone out of fashion, but some observers mention them as being the cause of penetrating abdominal wounds.

To draw up in figures an estimate of the comparative frequency of the wounds caused by one or other of these different projectiles would have only a very relative value. We have seen how it changes, according to strategic conditions, with the different periods

of the war, and even with the sectors in which the cases are investigated. Here, however, is a comparative table, from 479 observations of laparotomies :

Bayonet-wounds	3
Bullet-wounds	147
Shell-wounds	271
Grenade-wounds	58

It is more interesting to notice the comparative gravity of the wounds as shown by the number of recoveries or deaths observed after laparotomies :

	Cases.	Recoveries.	Mortality.
Bullets	147	81	45%
Bombs—petards	58	31	47%
Shell fragments	271	94	66%

We will now study the

ANATOMICAL LESIONS

in order to obtain practical information from them.

There are *five essential ideas* that seem to stand out from the anatomical lesions observed, and by the help of which these lesions may best be described.

(1) A certain number of penetrating wounds do not injure the viscera, even when the abdomen is traversed from one side to the other.

(2) A certain number of visceral lesions may recover spontaneously.

(3) There are some lesions which cannot possibly heal spontaneously.

(4) Multivisceral wounds are much more serious than univisceral ones.

(5) Associated abdomino-thoracic lesions are either benign, or extremely serious.

(1) A Certain Number of Penetrating Wounds do not injure the Viscera, even when the Abdomen is traversed from one side to the other.

In the first place, if the projectile stops, at the end of its course, in the abdominal cavity, it may conceivably insinuate itself, between the coils, and stay in the folds of the mesentery and the mesocolon, without in any way injuring the intestine or solid viscera, or confine itself to slight contusions. Bouvier and Caudrelier ([12], Obs. 9), in dividing the intestine, caused the ball to fall out: it had only bruised a loop of the small intestine; in another case (Obs. 11) the ball was loose in the abdomen, having only occasioned a chafing of the jejunum. Arcelin [75] twice extracted a shrapnel bullet wrapped up in the omentum (Figs. 1

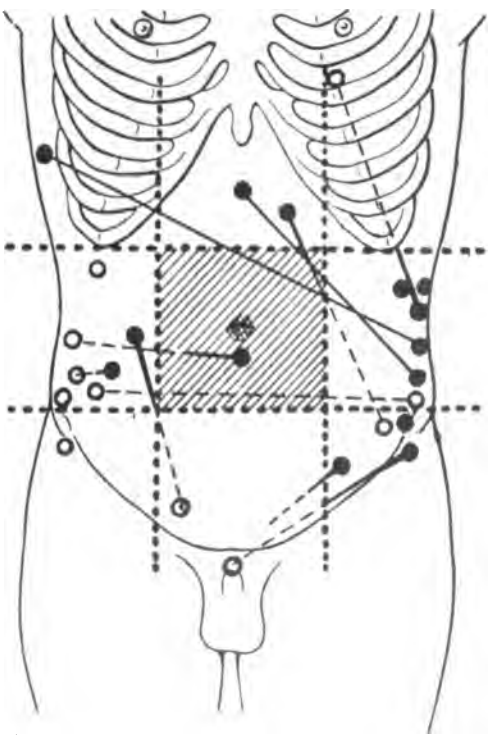


Fig. 3.*—Penetrating abdominal wounds verified without injury to a single viscera. Cuthbert Wallace [52].

* In this and all the following diagrams, orifices situated in front are represented by ; at the back by ; direction of the course by →.

and 2), and the observation of Delore [37] is still more strange, as he met with a pile of louis d'or which had fallen into the recto-vesical pouch!

The occurrence of a projectile stopping against the coils or gliding between them is rarer in proportion as the projectile is rugged. Thus it is seldom observed in the case of shell-wounds or those caused by trench mortars; at the point where the latter stops short there is nearly always a contused wound or perforation of the gut, however small the perforation may be.

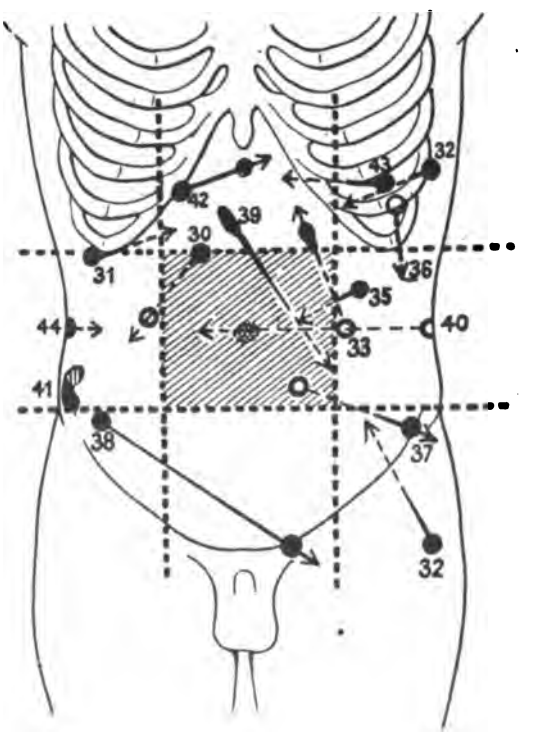


FIG. 4.—Wounds that have healed without operation and penetrating wounds, operated on, in which the absence of visceral lesions has been verified. (Rouvillois [38].) We see that neither the one nor the other belongs to the umbilical region.

P——, wounded by shell-fragments, November 4th, 1915, showed in the right iliac fossa a parietal wound of irregular shape, from which started a diverticulum penetrating into the abdomen. Median sub-umbilical laparotomy demonstrated a tangential rent in a loop of the small intestine without perforation, and a perforation of the omentum. *The projectile itself had remained in the parietes, only its point had perforated the peritoneum*

... the *viscera*. The man recovered. (Abdominal Cos. 2.)

... other case: the projectile may entirely traverse the abdominal cavity, implant itself in the opposite wall, or pass out, thus making a complete seton of the abdomen, and that *without visceral lesions*.

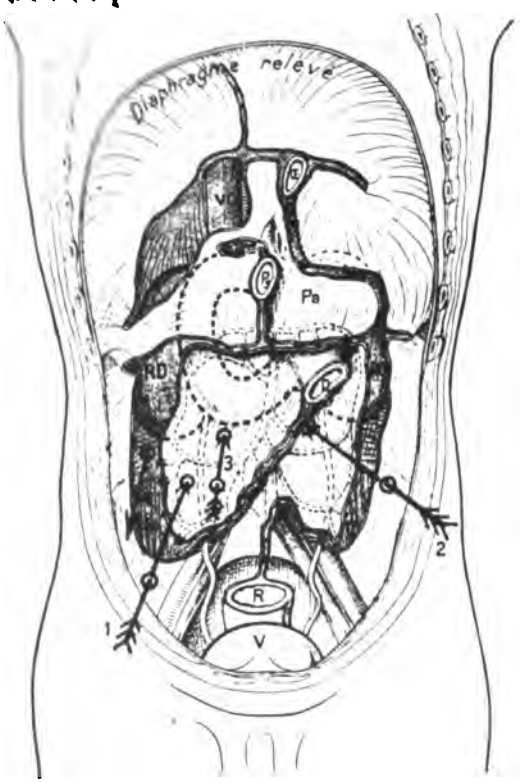


FIG. 5.—Non-visceral and non-vascular zones of the posterior abdominal region. 1, 2, 3: projectiles that, after having glided between the intestinal coils, may pass out at the back without grave lesions. 4: Projectile that, passing from back to front, may remain in a "meso," though approaching very near to the anterior wall. (The circles traversed by the arrows 1, 2, 3 represent the orifices of passage through the anterior wall.)

This has been observed in many instances.

In 275 operations examined by Tuffier [38] as to this point, 31 proved to be simple peritoneal penetrating wounds, or 11·27 per cent. This estimate is really too low, for it only applied to cases operated on, and there are many where the complete traversing of the abdomen is evident, but where the surgeon, even the interventionist, abstains from operating in the absence of all reactionary phenomena. Of these cases, which are fairly frequent, we should naturally find no traces in operations described.

Quite lately we extracted from under the skin, against the external edge of the right rectus at 2 cm. below the umbilicus, a piece of shell that had penetrated the right flank; being surrounded by omentum, it was obvious that the projectile had traversed the peritoneal cavity. The absolute localisation of peritoneal reaction, the absence of any affection of the general condition, and the long delay that had taken place, made us reject the idea of laparotomy. The patient recovered perfectly without the least fistula.

The preceding diagram by C. Wallace, consulting-surgeon to the English Army, represents paths of the projectiles verified by laparotomy where no viscus was injured, in spite of penetration or peritoneal passage (Figs. 3 and 5). We now reproduce a similar diagram by Rouvillois, in which, besides the peritoneal wounds that healed without intervention, and in which the projectile has been localised by radiography, we have added the simple peritoneal wounds verified by laparotomies (Fig. 4).

Anatomically, these facts can easily be understood. But on seeing the abdomen cut open, even in frozen subjects, the thing would seem impossible. We have to remember, however, that these openings are most often made on horizontal subjects, while the wounded are almost invariably hit standing. In this position the stomach, the transverse colon, and the mass of the small intestine have a tendency to stretch vertically; the free spaces between the viscera widen and the "mesos" (mesentery) stretch, while a considerable portion of the coils of the small intestines fills the pelvis.

But, above all, the course of the projectiles that do not reach the viscera (of which we have a demonstration in the diagrams of Wallace and of Rouvillois) is neither truly antero-posterior nor transverse, neither is it horizontal, *but all, or nearly all, are distinctly oblique*, and from front to back, from below upwards, from right to left, or vice versa. Hence a projectile may

easily pass the mass of the small intestines, at a tangent, glide along the mesentery between two loops, and reach the posterior region in one of the parts—few, it is true—where no important organ or important vessel is met with (see Fig. 5) It may also be tangential to the intestinal mass behind (Obs. 10, Rouvillois), and pass either within or without the loops of the colon.

One of our wounded, C——, May 19th, 1916, was hit in the epigastrium slightly to the right under the costal border by a piece of shell A wound as large as a five-franc piece gave access to the liver, the anterior edge of which was torn. There were no abdominal symptoms. No operation was attempted. During the following days a biliary fistula developed. It was very abundant at first, but gradually diminished. The man recovered. The radioscope showed the projectile a little above the right iliac crest, and against it, at 14 cm. from the spinal column.

The projectile had therefore damaged the edge of the liver, moved in front of the transverse colon, glided between the ascending colon and the mass of the small intestines to plant itself in the posterior wall.

One of Vertraeghe's patients [**] was traversed obliquely from the right lumbar region to the left flank by a cylindrical copper fuse 2 cm. long by 1 cm. in diameter. The projectile injured the lumbar roots, traversed a vertebral body, entered the abdomen to the left of the lumbar column, passed through it, and stopped under the skin of the left flank, after having perforated the anterior abdominal wall. It had carried in fragments of clothing. Laparotomy showed no intestinal lesion. The wounded man recovered.

There is another point in which the diagrams of Wallace and Rouvillois are in agreement: no projectiles are to be seen in the umbilical and periumbilical regions without visceral lesions. The projectiles least likely to injure any viscus are found in the

flanks, the iliac cavities, and more rarely the hypochondria.

Somewhat similar in results are the cases where the projectile has entered from behind, glided into the substance of the mesenteries, and ended by occupying an entirely intra-abdominal position but not an intraperitoneal one. We have seen two typical cases of this.

In the case of B—— we extracted from a lumbar wound a fragment of shell 5 cm. by 3 cm., situated 8 cm. behind the anterior wall, above and to the right of the umbilicus. This projectile had apparently penetrated the mesentery or the transverse mesocolon without injuring any hollow viscera. We shall see the interest of this case again in relation to the interpretation of radioscopic findings (p. 473).

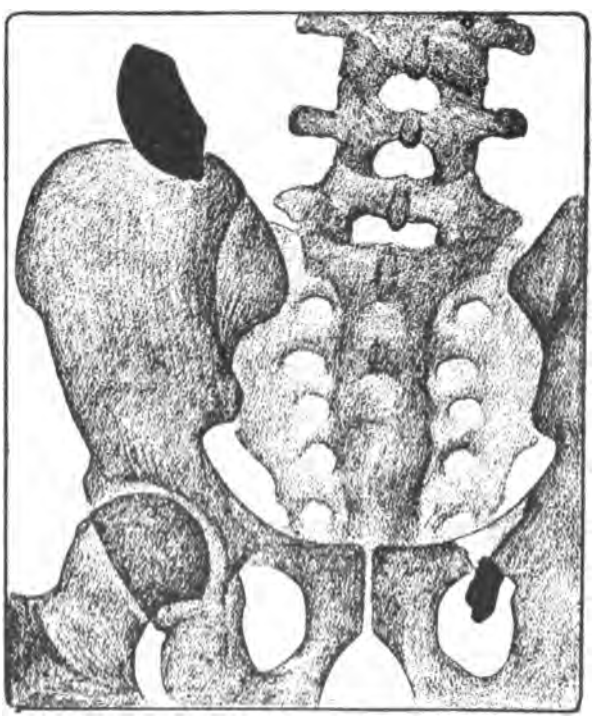


FIG. 6.—Small projectile which had perforated the bladder, the rectum, the small intestine, and the pubis. A large projectile that had remained subperitoneal.

The patient. H—— (see p. 517), whose case was

exceptional from many points of view, presented this special feature, that a larger fragment of shell (40 grammes of cast iron) having entered by the left ischio-rectal fossa, fixed itself, remaining subperitoneal, in a peritoneal fold situated between the cæcum and the external lateral and posterior wall. It was a radioscopic surprise to discover its presence, as there were no reactionary phenomena in that region. The foreign body was not removed until several months after the initial wound. The first operation had been concerned only with perforations of the rectum, of the bladder, and of the small intestine caused by a small fragment of shell that had entered by the buttock and lodged under the pubis!

Are we to conclude, from this, that intraperitoneal wounds, not visceral, will always be benign? No, certainly not, especially if it is not a question of bullets but of shell or grenade fragments, etc. The latter projectiles are septic, they bring in fragments of clothing, they make more irregular parietal breaches, with muscular damage often out of all proportion to the small size of the cutaneous orifices, and they may be complicated by gas gangrene (C. Wallace).

In addition to this, they have great liability to produce *visceral contusions*, from which may result late necrosis of the walls and the appearance of a septic peritonitis which has only been deferred.

There is another complication which modifies the apparent benignity of non-visceral wounds: that is *hernia*. Under the influence of abdominal pressure, either immediately or gradually, a piece of gut or omentum works into the orifice, remaining pro-peritoneal or intraparietal, or comes out at the exterior. If only the omentum is herniated, it isolates the abdominal cavity, and even if strangulated and later sphacelated, it will nevertheless have acted the part of a salutary stopper. An intestinal loop is much more dangerous: it has infinitely more opportunity, owing to contamina-

tion, of causing generalised peritonitis by propagation. Its size may also increase indefinitely, rendering the hope of spontaneous healing more and more illusory; or else, being strangulated, it may become gangrenous, and will be the seat of an artificial anus: the latter is the only favourable issue, provided this fistulisation is far enough away from the origin of the small intestine and near to the cæcum.

In short, penetrating peritoneal wounds without visceral lesion may be benign in the cases of a bullet arriving at slow speed; spontaneous cures are very frequent in such cases; they enter largely into the number of successes registered by the abstentionists. But we must bear in mind that, in the case of shell-wounds, the gravity is enormously increased, and, if there is a hernia, *e.g.* a large omental hernia, and still more if there is an intestinal hernia, the prognosis is very serious and intervention is necessary.

* * * * *

(2) A Certain Number of Visceral Lesions may heal Spontaneously

It is as regards the **small intestine** that this fact is the most contested. Text-books nevertheless admit that a minute perforation of the small intestine may heal of itself. It does so by the triple effect of its oblique passage, the mucous stopper, and the adhesions. The oblique passage through the wall prevents the super-position of the different planes perforated; the obliteration is effected by gliding. The mucous stopper prevents the issue of the septic intestinal contents; its role is still essentially mechanical. The adhesions, facilitated besides by the septic qualities of the mucous stopper, which give rise to a defensive reaction all round it, rapidly unite the injured coil to the viscera, to the gut and to the neighbouring parietal peritoneum. Thanks to these adhesions, the perforation is isolated from the rest of the peritoneal

cavity; the reparation of the orifice is gradually accomplished; the adhesions disappear later. The recovery is complete.

But in order that this process may play its salutary part, it is absolutely essential that the orifice should be small, with regular edges, so that the mucous membrane may be condensed and form a stopper there, and not become on the contrary a funnel leading towards the exterior. It is also essential that the adhesions should be able to form—that is to say, that the coils should remain stationary; they have a natural tendency to do so: paresis, dilation, and congestion are manifest in every diseased intestinal coil. It is necessary also that no external influence should induce an untimely movement.

The internal pressure must also not be excessive, otherwise the intestinal contents may be forced out. This would be the case in an empty or contracted intestine, in the "dog's intestine" of a fasting subject.

It is essential also that the intestinal contents, and hence the mucous stopper, should not be so septic as to infect the whole of the peritoneal cavity—a perforation very close to the stomach will be more septic than towards the middle portion of the small intestine.

It is also essential that the hæmorrhage from the intestinal wound should not be at all excessive.

Are so many favourable conditions ever realised in the wounds received in war? Certainly.

Some observations of Schwartz and Mocquot [34] are instructive in this connection: we find, for instance (Obs. 18, second series), that ten perforations caused by bullets, some as large as a lentil, others as large as a pin-head, were spontaneously obliterated.

Chevassu [35] has also witnessed the recovery of two wounded men in whom the perforation of the intestine was situated opposite the parietal wound—thanks to that, the intestine could evacuate its contents outwards and not into the abdominal cavity (these two,

amongst the recoveries that he mentions, are also the only ones that had undeniable wounds in the small intestine).

But such fortunate coincidences are very seldom realised. To begin with, it is rare to meet with small perforations, and it is still rarer to find them isolated. And that can easily be understood. A single perforation can only be produced by a projectile exactly tangential to the convexity of a loop, or again by a projectile at the end of its course, falling into the cavity of the intestine. Two orifices imply a path similar to the one we have described, permitting the passage of the projectile between the coils—that is to say, very oblique. But let the bullet or shell come in a decidedly antero-posterior or horizontal direction, and not one only, but several coils will be involved; the perforations will be 6, 8, or 10 in number. This happens frequently (see Figs. 9 and 10).

Now, however small their size, the multiplicity of these perforations renders the possibility of spontaneous healing very unlikely: accumulated on the same loop, they compromise its vitality, and this is more liable to happen since the mesentery may itself be affected. If, on the other hand, they are scattered over numerous coils, they necessitate more extensive plastic work, and also render more probable disseminated infection of the serous membrane.

Hæmorrhage is far from being slight. Very often it is disproportionate to the size of the perforation. Such abundant, peritoneal hæmorrhage, favourable to the development of peritonitis, may accompany a very small perforation.

As to immobility, one cannot count on that because of the many displacements of the wounded man between his fall and his bed in the hospital; the intestines are subjected to a violent shaking by the lifting up, the transport through the trenches, and above all by the journey in the automobile.

And, admitting that it does take place, how insecure this spontaneous repair of the intestine is likely to be! An observation of Chevassu's is a typical proof of this. A wounded man went to the water-closet on the sixth day, when his condition was excellent and his abdomen quite supple. The post-mortem showed eight quite small perforations, about 3 mm. in diameter, closed, with the exception of one, by the adhesions of the coils amongst themselves. Yet this plastic process had not resisted some rather sudden movements on the sixth day.

We perceive, by this example, how exceptional and uncertain it is for wounds of the small intestine to heal by abstention.

It is quite a different matter with the **large intestine**, or, more precisely with the *vertical portions* of the large intestine—the ascending and descending colon enjoy, in fact, exceptional privileges.

It is *only slightly mobile*; hence no collection of the infection; greater facility for the work of adhesions; and the relative frequency of tangential wounds. (Here there occurs a shadow in the picture: very often these tangential wounds are confined to a contusion, and the delayed loosening of the slough will be full of dangers!)

Again, *it has no circumvolutions*—we only meet with one or two perforations.

Being near the parietes, it can easily attach itself to them, either to limit by adhesions a stercoral cellulitis whose tardy opening to the parietes by the traumatic orifice would be one method of healing; or to send outward its own perforation as a hernia; or to establish at the first onset free communication with the exterior, the true artificial anus which in its results allows of the easy escape of fæces and gas, and the peritoneal cavity remains free. This is a considerable factor of safety.

Another peculiarity is that it possesses *an extra-*

peritoneal portion. Its width is evidently very variable; all forms of it are to be observed, from the clearly sessile colon, partly spread out against the lateral abdominal wall, to the colon with a mesenteric pedicle. In the first case, which is the most frequent, a projectile may reach the colon in three ways, each more favourable than the preceding: (*a*) The colon may be perforated where it is covered by the peritoneum, and in its extraperitoneal part: as this second perforation may give rise to a fistula immediately or in a short time, thus favouring a fæcal cellulitis, the peritoneal orifice will have so much less chance to open and infect the abdominal cavity. (*b*) The colon is perforated tangentially or at two neighbouring points in its extraperitoneal part, but by a projectile that has previously traversed the abdomen, very near the parietes, it is true. (*c*) The projectile has injured the colon, but its passage has been entirely extraperitoneal.

In all these cases the adhering surface of the colon cicatrises directly, or else a cellulitis ends in a fæcal fistula.

M—— was wounded by a bullet, June 20th, 1915. There was only a punctiform orifice below and outside the right antero-superior iliac spine. An oblique subperitoneal laparotomy, by following the track, came to the external surface of the ascending colon just above the cæcum; here the finger reached a focus contaminated by intestinal contents, but appearing very limited; we confined ourselves to inserting a drain. The patient recovered.

The radioscope showed the bullet to the right of the lumbar column, half-way up, 9 cm. in depth from the abdominal wall (Abadie).

Lastly, *the contents of the large intestine are less liquid* than those of the small intestine, and thus will have less tendency to escape by the perforations.

It is to be noted that all these reasons, favourable

to spontaneous healing of the wounds of the colon, are, on the contrary, aggravating factors as regards direct surgical intervention. Having little mobility, the colon is rendered difficult to explore, or to open for the facilitating of excisions or sutures; and, if one has recourse to Quénu's or Duval's liberation, it is at the expense of a rather long manœuvre, which fatally exposes large cellular spaces to septic contamination. The part not covered by the peritoneum is difficult of access and for surgical action; sutures there are painful, slow, and hold together badly. If burying of the serous membrane is not possible, fæcal fistula is almost invariable, however careful one may be to multiply the planes of suture. Finally, if the contents are less liquid, they are, on the other hand, extraordinarily septic, and an infection of the peritoneum in the course of operation is almost always fatal.

These facts relate, as we have said, to the vertical portions, and not at all to the *transverse colon*; the wounds of the latter, and particularly of the left angle, are as serious, if not more serious, than those of the small intestine. None of the causes of comparative benignity exist; on the contrary, the contents are more septic than those of the small intestine.

In the same way the *sigmoid flexure* often has a wide mesocolon, and is sufficiently mobile; but it has a tendency to occupy the true pelvis, where we are aware that infective foci are isolated and collect most easily.

We have here a case in which the very great mobility of the sigmoid flexure facilitated healing by the mechanism of visceral hernia with gangrene and an artificial anus.

Quenu [66] observed a colonial in whom a bullet, entering a little behind the left antero-superior iliac spine, made its exit by a large wound in the fold of the left groin. A loop of the ilio-pelvic colon, already

perforated, was protruding there. The loop sphacelated; and a spontaneous inguinal anus formed. The man recovered, and four months later Quénu effected the surgical closing of this anus.

We have to remember, then, that wounds of the colon frequently meet with anatomical conditions which allow of healing by abstention; on the other hand, laparotomy is particularly difficult and serious.

In the **stomach** perforations of the anterior surface, and even of the posterior surface readily cicatrise. In the latter case, however, a discharge may be formed in the lesser sac of the peritoneum, which one must know how to open and treat at the right moment. But there is one essential condition for the healing of stomach perforations—it is that the subject must be fasting, so that there is no tension of the chyme.

The wounds of the **liver** capable of spontaneous healing belong to the following types:

(1) Tangential grooves.

(2) Blind tunnels, complete setons made by projectiles not provided with sufficiently violent force to produce bursting lesions.

(3) Lacerations, or limited marginal contusions, without deeply irradiating fissures.

These different wounds, the last particularly, produce abundant hæmorrhages, which, however, stop spontaneously in a short time. An operation having for its object direct hæmostasis will often expose the patient to a recurrence of hæmorrhage, and if the latter can be arrested (sutures in "U form," plugging with a tampon), it will be because there existed great probability of spontaneous cessation.

Bullet-wounds close up on the outside, and the lesions evolve thus. The cases are numerous in which the radioscope shows a bullet enclosed in the substance of the parenchyma.

When there is a complete seton, it is very unusual not to find at the same time an associated abdominal lesion, or above all a thoracic lesion, which takes precedence over the former as regards prognostic importance.

The escape of bile is fairly frequent, especially in the case of irregular projectiles (shell-fragments or grenades), and when small splinters of ribs accompanying them add to and aggravate the lacerations. Here also the discharge gradually dries up, provided always that the wound is of small extent, the liquid not too abundant, and that there is no discharge into the main abdominal cavity—in the latter case the peritoneum would very seldom remain aseptic.

On the whole, except where there is great destruction, wounds of the liver have great chances of spontaneous healing.

The **spleen**, on the contrary, is so friable, and so gorged with blood, that traumatism rarely affects it without causing serious hæmorrhage, and in many cases total destruction. A simple tunnel perforation is very rare. One example can, however, be quoted (Duval [61]).

We will only study the **kidney** which has been hit by a projectile that has traversed, or is about to traverse, the abdominal cavity. Hence the lesion is secondary in interest compared with that of the viscera simultaneously injured. If the latter heal it implies the existence of the special conditions of benignity that we have already studied, and *a fortiori* the kidney will also heal. It suffices to recall the frequency with which wounds of the kidney improve after penetrating lumbar wounds. The very great facility with which the kidney bleeds as soon as it is injured or bruised explains the hæmaturia, often abundant and disquieting at first, but which gradually dries up. Afterwards, according to the case, healing proceeds regularly, or one intervenes secondarily to remove a

septic collection round the projectile, near or inside the kidney.

It is the same in the case of the wounds associated with penetrating wounds of the abdomen.

The **rectum**, too, is hardly ever involved except in connection with other organs, which are of predominant interest. The only eventuality that would seem to admit of the spontaneous cicatrisation of a wound of the rectum in its peritoneal region, is that of a bullet or small splinter with an exclusively pelvic course, reaching only the rectum and bladder, or the rectum and the sigmoid flexure, and causing perforations sufficiently narrow to bring about a purely local reaction, a peritonitis limited to the pelvis. When the rectum is involved in its extra-peritoneal part, the likelihood of spontaneous healing is greater still, even if the lesions are not produced by small projectiles. If the passage of communication with the exterior in the sacro-coccygeal region is widely opened we can observe the progressive cicatrisation of the rectal wound.

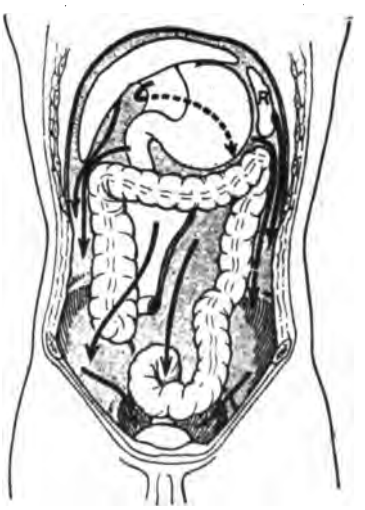


FIG. 7.—The true pelvis is the "collecting-sink" of fluids discharged into the abdominal cavity (blood, intestinal contents, etc.).

The same remarks may be applied to the **bladder**: in wounds of the same degree the gravity is manifestly greater in lesions which affect the peritoneal region. We nevertheless observe spontaneous healing of perforations of the bladder by bullet, shrapnel, or small projectile entering the suprapubic or transpubic part.

Sometimes the bladder is obliterated at once, and the cicatrisation proceeds plane by plane; sometimes fistula of the passage, purely urinary, or pyo-urinary, is set up as an intermediate condition. Cases of this kind are not extremely rare.

One observation is applicable to all the pelvic organs, and to the iliac cavities and the hypogastrium. All intra-abdominal effusions have a general tendency to descend towards the pelvis, which thus plays the part

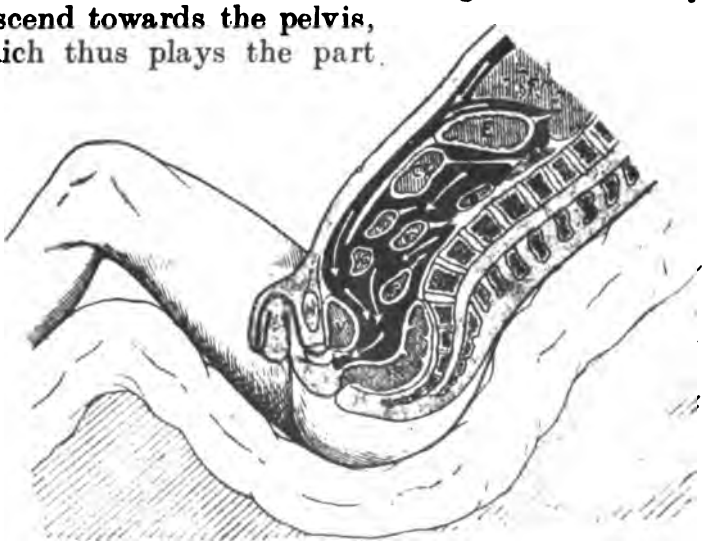


FIG. 8.—The pelvis is the "collecting-sink" of the peritoneal cavity, particularly in Fowler's position.

of a true "collecting-sink." The organs situated low down that we are now considering are evidently placed in privileged conditions, as blood or fæcal matter coming from their perforations will proceed to the collecting-sink without traversing or infecting the general peritoneal cavity (see Figs. 7 and 8).

We have now analysed the anatomical conditions in which the different viscera, considered separately, are likely, when involved by a penetrating abdominal wound, to heal spontaneously—that is to say, to benefit by abstention.

The chances of healing vary with the different organs. Very poor in the case of the intestine, they are considerable, in comparison, for the liver, the stomach, and the ascending and descending colon.

To sum up : *Spontaneous healing of the small intestine is exceptional*—it is a risk that would not justify any confidence in treatment by abstention. *Spontaneous healing of the stomach, the colon, and above all of the liver* are sufficiently frequent, on the contrary, to justify abstention in certain cases. As Tuffier says, "There is matter for reflection here for irreconcilable operators."

. . . . . .

(3) There are Lesions that cannot possibly be repaired spontaneously

And there are also some that will remain, whatever one may do, beyond all therapeutic resources, even surgical ones.

But what is interesting is just to draw attention to these "limited cases"—that is to say, on the one hand the lesions which cease to become spontaneously curable and hence necessitate direct surgical action, and, on the other hand, those whose gravity forbids the hope of success in any intervention whatever. But we must never forget that we always have in view the number of cases in which laparotomy is, first, necessary ; and, secondly, may still be found efficacious.

In this connection everything is dominated by the nature, the form, the weight, and the dimension of the **projectiles**.

There are small projectiles, and there are large ones.

Large fragments, large splinters of bombs or shells, arriving with very great force and erratic gyration, cause considerable damage, which too often nothing can set right (see Fig. 17).

The abdominal wall, cut and sometimes torn, allows a voluminous visceral hernia to present. Sometimes

it is the injured viscera that thus protrude; sometimes it is intact coils, and one cannot judge from their aspect of the extent of the deeper lesions: multiple intestinal sections, pieces of coils of intestine at the end of their torn mesentery, extensive portions of bowel floating free, remaining attached to the mesentery higher up, the end of the mesentery having been projected far from the corresponding segment, large vessels torn, solid viscera burst or crushed. All these may be immersed in blood and intestinal contents. If material reparation of the lesions were operatively possible, death would follow notwithstanding, as the hæmorrhage and shock deprive such patients of all resistance, and their tissues of all possibility of reaction. Death is at hand, whatever one may do; the rapidity of the intervention and the skill of the operator will, in any case, be in vain.

Thus it happened that in one of Vertraeghe's patients [*] a projectile having passed through the abdomen transversely, they found in a portion of the small intestine, of about a yard in extent, *four complete sections* of the intestine, two small segments of the small intestine *free* in the abdomen, and *nine* large perforations of the intestine, into several of which the thumb could easily have been inserted. Besides all these wounds there were three other perforations scattered over the small intestine and one perforation of the cæcum.

We have seen an analogous case on p. 333

Here is an example of still more serious lesions: G—— was struck on September 24th, 1915, by a shell that caused on the right side, a little below the umbilicus, a wound as large as the palm of the hand; a bundle of coils of the small intestine had escaped thence; three perforations and a complete section could be observed; the pulse was uncountable. Immediate intervention (second hour). After having treated the visible lesions (suture of the perforations,

resection, and anastomosis in the case of the complete section), a vertical exploratory laparotomy was made: in the neighbourhood of the cæcum the small intestine was irregularly jagged and torn, as was also the cæcum, close to which was extracted a heavy *fragment of shell 9 cm. long by 2 cm. in width and 1 cm. in thickness*. A resection of the cæcum and a latero-lateral ileo-sigmoid anastomosis were made. The wounded man died the following night. (Abadie [33], Obs. 11.)

The very gravity of the lesions has justified, from the point of operative decisions, two diametrically opposite attitudes. "These wounded have nothing to hope from medical treatment," says Sencert; "one should therefore operate without hesitation, as intervention may here and there produce some astonishing success!" Gosset, on the contrary, considers that the great traumatisms of the abdomen caused by shells with lesions of the parietes and escape of the viscera demand, as a rule, abstention. When the lesions are obvious, this is evidently the wiser course. But very often the deep lesions cannot be perceived, and can only be recognised in the course of an operation; except in extreme cases, it is better to give the patient the benefit of the chance.

Among the *small* projectiles, bullets arriving from a short distance cause wide perforations, detachments, and even explosive lesions. Splinters of shell, even small ones, have nevertheless their sharp, jagged edges, and, even more than their volume or their extent, the irregularity of their form and movement explains the havoc wrought by the small explosive projectiles of the trenches. Whatever organ may be involved, contused and irregular wounds, with ragged edges, are doubly formidable: they bleed, and they have a deplorable tendency to marginal necrosis. Besides, these projectiles, are always contaminated and carry in with them fragments of clothing which are particularly septic,

Let us now consider the damages they cause.

In the **small intestine** we meet with lesions of every degree, from perforation to detachment and bursting. When they attain the dimensions of a sixpence, *perforations* may be considered incapable of spontaneous obliteration. *A fortiori*, when the edges are irregular, contused, ravelled out; in many cases the peritoneum is roughened, frayed, torn all round, or in patches.

The multiplicity and the surroundings of the perforations compromise the vitality of the whole segment of the coil; the same happens with the perforations of the mesentery level with the coil, whether the latter is involved or not.

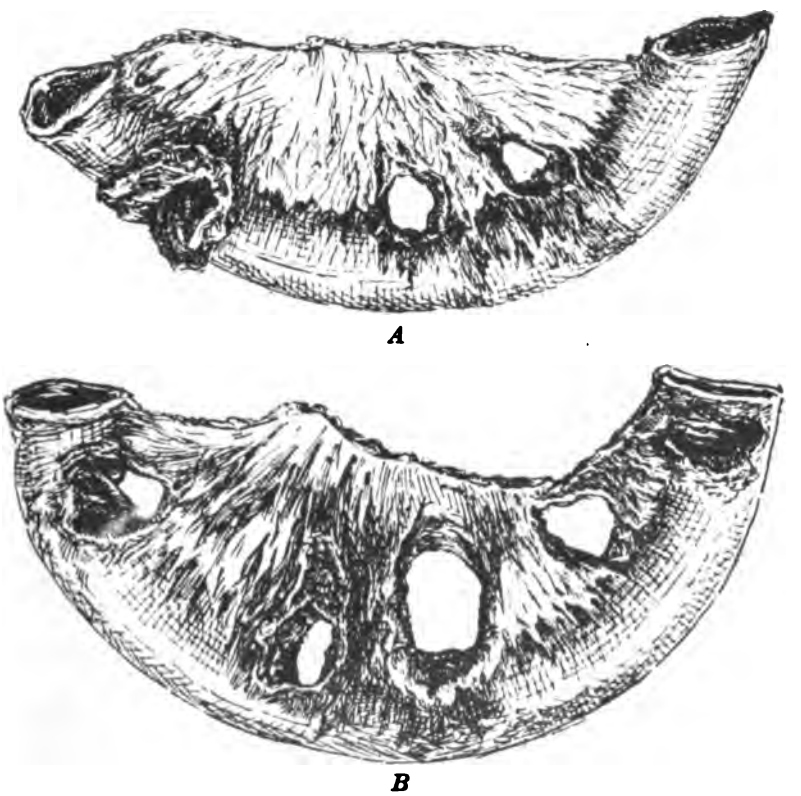
Incomplete section, transverse or oblique, is one degree higher in intensity; the edges separate. It is in vain that the lining forms a little marginal pad—the wound remains gaping. *Complete section* reaches as far as the mesentery, itself most often involved to a variable depth. Another type of lesion is the *detachment of the mesentery*, either above without wound of the intestine at this level, which nevertheless remains non-vascular and doomed to necrosis; or associated with an intestinal section. When affecting a single or neighbouring coils, perforations and even complete sections may heal after one or several resections of variable extent.

The specimens represented by the Figs. 9 and 10 are very instructive; we see collected there every type of perforation.

Here follows their history, at once encouraging and deceptive. Encouraging, for it shows that multiple and grave lesions are susceptible of healing, thanks to intervention; deceptive, for pulmonary complications irresistible in their development may render the most powerful efforts vain.

The specimens represented in Fig. 9 came from E——, wounded June 7th, 1916, by fragments of

shell, one passing under the left crural arch and remaining intraparietal; the other penetrated the abdomen at the level of the middle of the left rectus. Considerable pallor, imperceptible pulse, shock. General rigidity of abdomen, no motion, no flatus, urine clear on catheterisation.



A

B

FIG. 9.—Loops of the small intestine resected in the case of E——, p. 358 At the top (*A*), large perforation, causing a section of two-thirds, and two wide perforations involving the intestine and the mesentery. Lower figure (*B*), three large perforations of the intestine, and two large perforations of the mesentery.

After 1,000 grammes of saline and adrenalin, camphorated oil, and the application of heat, the wounded man was operated on (at the ninth hour).

Median subumbilical laparotomy; very abundant bleeding; repair of the lesions apparent in the dilated subumbilical *loops of the small intestine*. There were found, at some distance from each other, separated into four groups: a *perforation* large enough to admit the thumb (transversely closed in two layers); one wider *perforation* (lozenge-shaped resection, transverse suture in two layers); in a length of about 30 cm. *three wide perforations* of the small intestine, with edges turned outwards, of which two encroached freely on the mesentery; *two large perforations of the mesentery* independent of and tangential to the intestine (resection of 35 cm. and end-to-end anastomosis) (Fig. 9, *B*); again, in a length of 25 cm., a *wide perforation* of the small intestine, causing a *transverse section of two-thirds* of it, the edges much everted, and *two tangential perforations* of the small intestine detaching the mesentery (resection of 30 cm. of the intestine, end-to-end anastomosis (Fig. 9, *A*)). Drying of the abdomen by warm compresses of saline; 100 grammes of ether after rapid exploration of the pelvis, where nothing abnormal was observed. Large drain in recto-vesical pouch. Suture in one plane with bronze thread. Duration, 55 minutes. Drop by drop. Fowler; strychnine, fluid diet.

On the fifth day the situation was as follows: temperature normal, pulse 120, but the drain showed escape of urine. It was therefore evident that the projectile has reached the bladder by a peritoneal orifice passed unnoticed, which would happen the more easily since the clear urine gave no indication of the least vesical lesion. And, in fact, *the radioscope* showed the projectile behind the root of the right thigh; it had passed by the sciatic notch.

On June 18th: temperature 38·5; pulse 120. Cystotomy was performed and a Freyer's drain was inserted, and a continuous drop-by-drop irrigation made into the bladder and the recto-vesical pouch.

The condition improved, and on the 21st recovery was looked upon as a certainty.

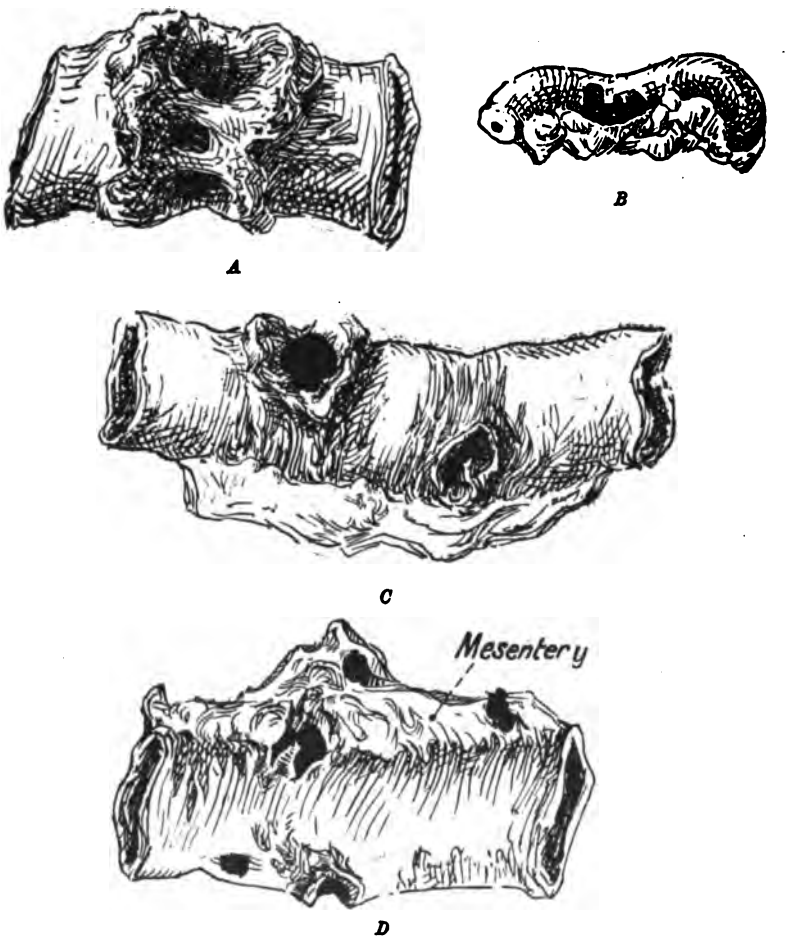


FIG. 10.—Specimens from a laparotomy with appendicectomy and triple resection performed on the wounded man D—— (see p. 362). Recovery. *A*, wide perforations, united, leaving only two mucous bridges remaining. *B*, perforated appendix. *C*, multiple perforations of medium dimension. *D*, small perforations of the intestine, but multiple perforations of the mesentery, interfering with the blood-supply.

But at this moment signs and symptoms of *diffuse broncho-pneumonia of the right lung* appeared. From

that date first one segment and then another gave signs of breaking down; the left base was similarly affected. Purulent expectoration grew more and more abundant. The patient sank, and died on July 4th, when the intestinal lesions had been cicatrised for some time and the bladder was going on well.

D——, on July 31st, received a small fragment of shell in the left iliac fossa. Median laparotomy (fifth hour) evacuated a great deal of blood, mixed with carrots, lentils, undigested peas, etc. Evisceration showed that the upper part of the small intestine was intact. But in the lower part there were found and successively operated on:

(*a*) Lateral perforation of the rectum (suture in two layers).

(*b*) Lateral perforation of the appendix (appendicectomy) (Fig. 10, *B*).

(*c*) Perforation of the mesentery (closed).

(*d*) Three perforations, two of them in the small intestine, closer together (resection of 8 cm., end-to-end anastomosis). See Fig. 10, *C*.

(*e*) Wide perforation of the small intestine soaked in green intestinal contents (resection of 6 cm., end-to-end anastomosis) (Fig. 10, *A*).

(*f*) Three small perforations of the small intestine, with three perforations of the mesentery impairing the vitality of the gut (resection 12 cm., end-to-end anastomosis) (Fig. 10, *D*).

The projectile was found in the recto-vesical pouch, Ether, hot compresses. Drainage. Syphon in recto-vesical pouch. Closed in one plane. Duration, 1 hour 10 min. Normal course. Recovery.

We must also note the intestinal lesions caused by "bursting." Stern, for instance, observed them twice, once in the small intestine by the side of an almost complete section there were two small wounds side by side, on the free margin of the intestine (Case

30); the section and the perforations were close together on the same loop. Another time he observed it in the large intestine—one single shell-fragment, penetrating from back to front, had produced in the cæcum and in the ascending colon two large rents and three punctiform orifices, all situated on the anterior wall of the intestine (Obs. 18). "The phenomena can only be produced when the projectile surprises the intestine at a moment when the latter is distended with fluid. This is just what causes the special gravity of this sort of intestinal wounds, for at the operation fæcal liquid is found diffused in the peritoneal cavity, except in the case of an eviscerated loop" (Rochard)

In the **stomach**, though a quite anterior penetrating wound of small dimensions has a great chance of healing spontaneously, it is not so if a marginal wound reaches the vascular belt that surrounds the stomach; when a posterior perforation has produced an abundant flow of blood or of gastric fluids into the posterior cavity of the omentum; when the wounded man has just eaten, in which case there will almost certainly follow the escape of its contents; when, lastly, it is a question of extensive wounds or bursting. In the latter case it too often is to be feared that all intervention will be ineffectual.

In the case of a wounded man operated on by Gosset, the bullet, by bursting, made a breach in the greater curvature large enough for the fist to enter; the great omentum was detached for 15 cm.

In such cases the lesion is in itself difficult to treat, and it is rendered still more so if it is accompanied by a great outpouring of septic fluid into the peritoneum.

The **transverse colon** is open to the same comments as the small intestine. And, in estimating the probability of spontaneous healing, one could not count on the fortunate accident of a free spontaneous communication with the exterior.

In the **ascending and descending colon**, the benignity of wounds is not so probable in the case of shell-fragments as with rifle-bullets or shrapnel. In most cases the damage is extensive, the lacerations wide, and the hæmorrhage abundant. The wound extends to the intraperitoneal region by an irregular aperture, so that some of the intestinal contents may fall into the abdominal cavity; they are then infinitely more septic than when coming from the small intestine, and thus

FIG. 11.—Typical explosion of the liver by bullet. It was a thoraco-abdominal wound, with multiple lesions of the lung, liver, and right kidney. Abstention; death. Cotte and Latarjet [44], Obs. 11.

the comparative benignity of the wounds of the colon and those of the small intestine is reversed. Extensive wounds of the colon, except in the case of a simple wound making an artificial anus permitting complete evacuation outside, are of the greatest gravity.

In the region of the **liver**, fissures or grooves that enter the parenchyma somewhat deeply give rise to

hæmorrhages and discharge of bile which are not prone to spontaneous healing (Fig. 11 and Plate I, p. 462). Similarly, very small projectiles (splinters of grenades) excavate, by their gyratory movement, veritable caverns in the hepatic tissue.

Le Fort has reported a typical case of this: hit in the paravesicular region, a patient developed a limited hepatic necrosis, and eliminated a necrotic mass from the right lobe weighing 200 grammes. Death resulted from septicæmia and hæmorrhage. The autopsy showed a smooth single cavity large enough for the fist to enter, open to the outside, without pleural or peritoneal communication, and without infection of the serous membranes.

FIG. 12.—Wound of the upper pole of the spleen. Type of burst with fissures to a distance. Considerable hæmorrhage. This spleen was herniated with the great cul-de-sac of the stomach into the left pleural cavity through a hole in the diaphragm of 6 cm. There was simultaneous burst of the left kidney. Death ensued. Cotte and Latarjet [44], Obs. 6.

Unfortunately, in such cases there is very little to be expected from an operation; suture and V-stitches in the injured tissues will not often arrest hæmorrhage, any more than plugging, and it would be inadmissible to suggest here free opening up, to prevent infective complications.

The **spleen**, when it is involved, does not heal of itself, and serious hæmorrhage from it is always dangerous. The only admissible surgical action is ablation (see Figs. 12 and 13).

The **kidney** has a tendency to spontaneous arrest of

the hæmorrhages of its parenchyma; but, in order that this may take place, the capsule must have

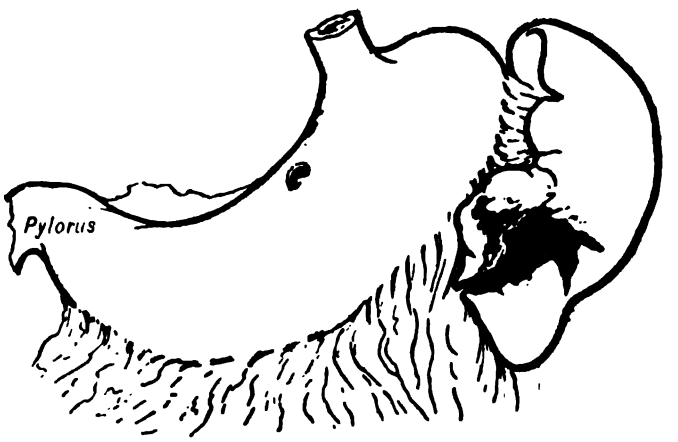


FIG. 13.—Punctiform perforation of the anterior surface of the stomach. Small, limited, marginal wound of the *spleen*, which was, however, sufficient to induce fatal hæmorrhage. Simultaneous perforation of the left lobe of the liver, by shrapnel. Cotte and Latarjet [44], Obs. 14.

remained sufficiently intact to be inextensible, and the renal tissue must not have been too deeply lacerated. When the fissures are deep, when there is bursting (Figs. 14 and 15 and Plate 1), and still more when there is rupture of important vessels (Fig. 16), the hæmorrhage rapidly becomes grave and fatal.

When the wounds of the **bladder** and **rectum** are somewhat extensive, they are rarely isolated, but it is certain that in the case of either of these two organs an intraperitoneal perforation that is not absolutely punctiform, or

FIG. 14. — Bursting of the upper pole of the left kidney. Internal hæmorrhage; nephrectomy; death. The projectile had perforated the small intestine, traversed the diaphragm, and finally lodged in the posterior mediastinum. Carpanetti [88].

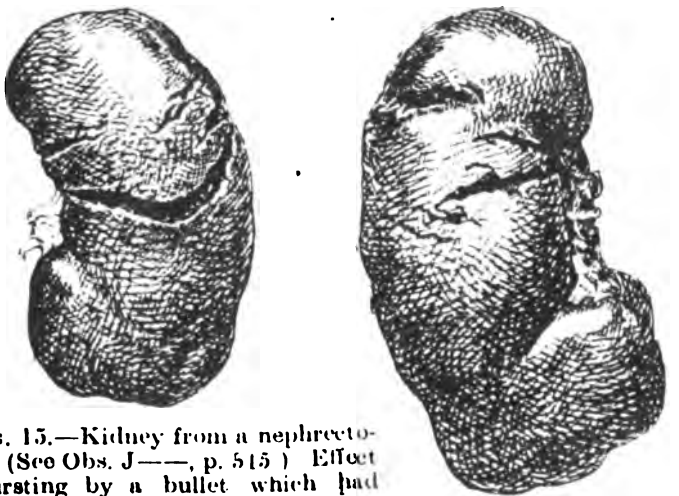


FIG. 15.—Kidney from a nephrectomy. (See Obs. J——, p. 515.) Effect of bursting by a bullet which had traversed the upper pole. Also section of the colon. Serious hæmorrhage. Laparotomy; recovery.

FIG. 16.—Effect caused by the bursting of a bullet on the kidney (left kidney, posterior surface) with traumatic section of the pelvis and the renal vessels. The same patient presented the other lesions shown in Fig. 18. Cotte and Latarjet [44], Obs. 8.

is contused will have no chance of healing spontaneously. This is the case with wounds caused by shell-fragments and trench mortars.

G——, wounded April 26th, 1916, by a large fragment of a grenade, showed a large wound of the left buttock near the point of the coccyx, from which blood was flowing very freely; the abdomen was painful, the pulse uncountable; catheterism collected drop by drop a mixture of blood and urine. At the *laparotomy* (seventh hour) the

blood came from a small perforation of the vesical peritoneum; after dressing the intact intestines with ether and forming barriers with saline compresses, an incision was made in the vesical peritoneum, when a perforation of the bladder was found; this was enlarged; the finger then felt in the bladder, which was full of blood, a long projectile (Fig. 17); this was taken out, covered with portions of the bladder; it was 7 cm. long by 2 cm. wide; the *fundus of the bladder was reduced to pulp*. The large cavity was isolated by suture of the peritoneum, and a drain was placed in the recto-vesical pouch; then the bladder was inosculated to the hypogastrium and a syphon-drain was placed at the top, while a catheter for continuous Dakin solution was tied into the urethra.

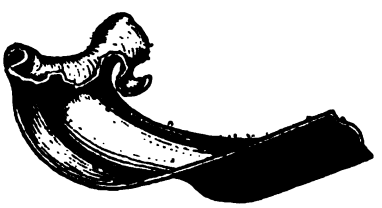


FIG. 17.—Fragment of grenade 7 cm. by 2 cm. which had divided the rectum and broken into the fundus of the bladder: (Obs. G., p. 367)

Then the buttock was laid open, and *a transverse section of the rectum was found*. A large rectal tube was inserted, the edges of the wound in the rectum were freshened and sutured, and two Dakin tubes were placed between the rectum and the bladder. Nevertheless, death took place the next day. (Abadie.)

. . . . . .

Complications.—All the lesions we have just been considering are rendered much more serious if there exists one of the following common complications: hæmorrhage, escape of the intestinal contents, traumatic hernia, or septic infiltration of the retroperitoneal tissue.

Intra-peritoneal *hæmorrhage* is constant, but variable in quantity. When abundant, it may come from the mesenteric or omental vessels, from an extensive

wound of a solid viscus such as the liver and spleen, or from a large vessel (renal or iliac artery). But as a rule—and this is the most serious—it comes direct from the wounds of the intestines; out of proportion to the dimension of the lacerations and the calibre of the vessels attacked, this hæmorrhage is slow, progressive, and continuous; and it does not encounter in the peritoneal cavity the causes of limitation which arrest a hæmothorax.

How many times on opening the abdomen, one sees black or even red blood flow out in abundance, without any tendency to coagulation! It comes from everywhere, from the pelvis, the flanks, from between the coils; one stops it, but it still continues, and at first one has the impression that the source of the hæmorrhage is a large vessel or a solid organ ruptured. Now, very often it is none of these; it is blood flowing from dependent parts. When it is over one recognises that its only cause has been laceration of the small intestine, without any important hepatic, splenic or vascular lesion.

Such **hæmorrhage** is the cause of anæmia, of abdominal reaction, and of the diffusion of infection. Hence its gravity.

Vignard writes, not without irony: "To speak paradoxically, I should be almost tempted to suspend all intervention on a man wounded in the abdomen or the small intestine, on condition that I could be assured that he was not bleeding!" Now, as a rule, he does bleed! And very difficult it is to say what is the gravity of the hæmorrhage, for even with vascular sections of the mesentery, the wounded die of intraperitoneal hæmorrhage, with the abdomen still flat and with intense pain.

The lesser cavity of the peritoneum may be the seat of a hæmorrhage whose origin is in the neighbouring organs. It gets gradually distended, and the resulting tumour forces out the anterior abdominal wall.

The same thing is observed with the retroperitoneal hæmatomata arising from organs such as the pancreas and the duodenum, or from vessels such as the branches of the cœliac axis and the vessels of the root of the mesentery. It is often a question of posterior transverse tracks (Fig. 18). The hæmorrhage may be great enough "to displace the small intestine, to raise the colon, and bring the lateral portion of the posterior wall into contact with the

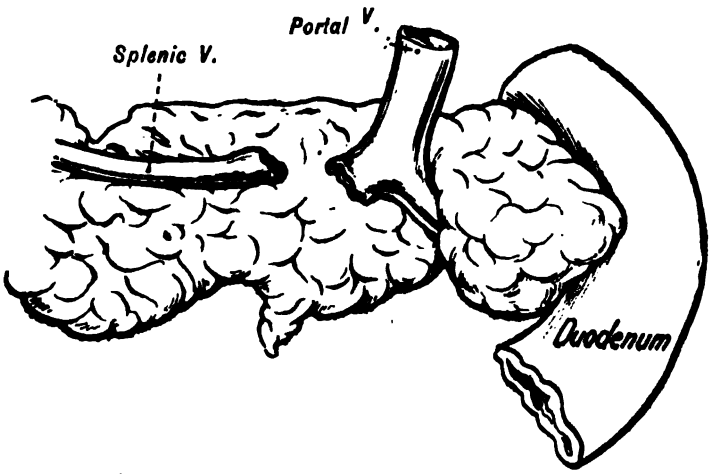


FIG. 18.—Laceration by bullet of the posterior surface of the pancreas with section of the splenic vein. The same bullet entered the lumbar region and burst the kidney (see Fig. 14), struck the pancreas and the lower surface of the left lobe of the liver, perforated the small omentum, and then lodged in the epigastric abdominal wall. Hæmorrhage occurred both in the lesser sac of the peritoneum and under the posterior parietal peritoneum. Cotte and Latarjet [44], Obs. 8.

anterior wall. Such a hæmorrhage appears like a large red tumour; the peritoneum that hides it may be intact or may present orifices from which the blood flows slowly." "Such cases are often fatal, either from the hæmorrhage itself or from injury to the pancreas. The shock is considerable, whether produced by the actual extent of the wound

or by interference with the sympathetic." (C. Wallace [52].)

Escape of the intestinal contents is less frequent than hæmorrhage, but it is at least as serious.

For in the abdomen we do not meet only with intestinal fluid, gas and bile, mixed with blood; we also encounter alimentary débris, bones, French beans, lentils, sweetmeats (Bouvier and Caudrelier); or, better still, worms, whole or divided by the injury! (see Obs., p 376).

One can readily imagine that such contamination of the serous membrane, especially if it has gone on for some time, will considerably diminish the probability of healing, even after operation. Besides, Quénu has clearly shown, in studying the second series of cases by Bouvier and Caudrelier, that deaths occurring rapidly after operation took place most often in cases where, on opening, they had found the abdomen full of blood, especially when the blood was mingled with fæcal matter.

Visceral hernia includes either the omentum or the intestine, and the latter may or may not be itself injured.

For the most part, if one disregards the herniated omentum which might cause by obliteration a deceptive hæmostasis, profound lesions of the intestine reveal themselves by an issue of blood or fœtid gas mingled with intestinal contents. If the herniated intestine is itself involved one cannot conceive of recovery as possible, unless it were an isolated lesion, widely gaping (an artificial anus), and situated low down in the small intestine. As a rule, such lesions are fatal if left to themselves, and hold disappointment in store for the operator.

This is still more the case if we consider complex eviscerations, such as the liver and omentum, the liver and colon or intestine, and the multiple coils of the intestine.

Infection of the retroperitoneal tissue proceeds from two sources, from the intestine and from the *bacillus capsulatus* of gaseous infection. It is usually met with in the retroperitoneal wounds of the colon, and its appearance is so delayed as sometimes to await the apparent external closing of the wound. But it may also accompany the dorsal wounds caused by shells, with hæmorrhagic infiltration of the parietes. The appearance and the evolution of gaseous infection are then rapid, the result is speedily fatal, and gases have been found, says Wallace [**], in the distended vena cava.

. . . . .

(4) Multivisceral Wounds are much more Serious than Univisceral

The term "multivisceral" is only applied to the wounds of several abdominal viscera.

The most frequent association is that of the small with the large intestine; next in order come the simultaneous wounds of the large intestine and one of the neighbouring viscera (stomach, liver, kidney); lastly come the simultaneous wounds of the small intestine and other viscera (spleen, stomach, liver, bladder, etc.).

And this manner of grouping—small and large intestine, colon and viscera other than the small intestine, small intestine and viscera other than the colon—corresponds also to differences in gravity.

From the statistical table of all the laparotomies published (see p. 396), we gather the following figures:

Multivisceral wounds treated by laparotomy:

	Cases.	Deaths.
Small and large intestine	65	55 (84 per cent.)
Colon and other viscera	32	27 (82 ,,)
Small intestine and other viscera . . .	25	22 (88 ,,)
Other viscera . . .	19	16 (88 ,,)

This gives a total mortality of about 85 per cent. for the multivisceral, while it is only 62 per cent. for the univisceral cases.

This difference is striking.

Does it arise from the larger number of the intestinal wounds? Not entirely, for when we were considering univisceral wounds we found instances of multiple wounds of 4, 9, and even 12 perforations and sections that recovered.

Quénu, after discussing a series given by Bouvier and Caudrelier, accused the large intestine of being the essential factor of aggravation; but, from the figures just quoted, which bear on a very much larger number of cases, it would not seem to be so. On the contrary, the large intestine would seem to afford the same coefficient of benignity in these cases as characterises its isolated wounds. When attacked alone it produces a mortality of 54 per cent. as against 65 per cent. for the small intestine. When taking part in multivisceral lesions without lesion of the small intestine, it gives a mortality of 82 per cent., while multivisceral wounds with lesions of the small intestine without lesions of the colon stand at 88 per cent., and the multiviscerals in which the small and large intestine are simultaneously involved yield a mortality of 84 per cent. The factor of aggravation would therefore seem to be the small intestine.

In the following case the lesions of the small intestine manifestly surpassed those of the large intestine:

M—— was struck on September 19th, 1915, by a shell that caused a small wound 6 cm. below the right antero-superior iliac spine. The parietal rigidity was very marked; there was no flatus; the face was drawn and pale, and the nose cold.

At the twelfth hour lateral laparotomy, right side, along the external edge of the rectus, showed abundant intraperitoneal hæmorrhage; progressive evisceration revealed *two big lacerations of the small intestine,*

longitudinal and irregular, at 80 cm. from each other; on each of these resections an end-to-end anastomosis was performed. In *the cæcum* there was a *perforation* of 1 cm.; this was sutured; at another point there was subperitoneal ecchymosis and a non-penetrating wound; this had purse-string sutures. Ether; pelvic drainage. Recovery. (Abadie [11], Obs. 9.)

That associated wounds of the large intestine should be more serious in themselves than when the colon alone is involved is, however, quite natural. An appreciable number of isolated lesions of the colon are only slightly or not at all intraperitoneal. On the other hand, the fact that other viscera have been affected implies that the passage of the projectile has not remained localised in the lumbar region or flanks, but has traversed the peritoneal cavity; under these circumstances, the lesions of the large intestine could hardly be benign—on the contrary, owing to gaping perforations, to the issue of solid contents, and to the extremely septic qualities of the contents, they are of exceptional gravity.

What above all contributes, as it seems to us, to give multivisceral wounds so dark an outlook is not only the greater importance of the lesions themselves but also the *dissemination* of these lesions; hence arises an initial diffusion of the foci of infection, and especially a shock to the sympathetic system that is much more marked and injurious. This is immediately shown by more extensive and more violent pain, and its action is verified by the subsequent atony of the tissues, and the delayed and sluggish cicatrisation of the visible wounds—the "trophic" shock has paralysed the powers of reaction and defence. Why should it not be the same here as with the limbs, especially the lower limbs? The abnormally augmented gravity of disseminated lesions which affect, not one limb only but both symmetrically, is a matter of common

observation, is it not ? Do we not see the phenomena of shock most markedly present in these cases ? It is the same with the abdomen.

This is also the explanation of the gravity of abdominal wounds that are complicated by extra-peritoneal visceral lesions. It is in the pelvic region that this association is the most formidable. The bladder and the rectum are two reservoirs whose rupture, or simple traumatic leakage, are equally serious, the first because its fluid contents filter everywhere and become infected, the second because these contents are from the beginning extremely septic. The fat and connective tissue that surround them form a region all ready for infection. Finally, these pelvic wounds are most often wide, complex, and have extensive detachments or tracks.

The wounded man G——, whose story was told on p. 367 as an instance of serious wound of the bladder, had also a transverse section of the rectum.

Here are other examples of eminently complex lesions.

M—— was struck on September 18th, 1915, on the left buttock by a small fragment of shell which passed out by the left iliac fossa, causing a wound as large as a two-franc piece with escape of a voluminous omental fringe, and a continuous flow of fœtid blood. There was no micturition; the abdomen was painful everywhere; there were shock and an uncountable pulse. Median subumbilical laparotomy at the sixth hour followed the resection of the *herniated omentum*; exploration by progressive evisceration showed: *complete section of the small intestine at two different points* (for this double resection was employed, with end-to-end anastomosis, one with Murphy's button), lateral, and almost posterior subperitoneal laceration in the rectum—probably also in the ureter—an *extensive rent in the bladder*. Suture of the bladder was made, and catheter inserted; drainage of the pelvis

by the buttock and the hypogastrium; drain at the traumatic orifice. Cleansing of the abdominal cavity, where blood, fæcal matter and a *worm* were found. Ether, 150 grammes; closed up in one plane.

Death, however, took place in the night, as could easily be foreseen. (Abadie [11], Obs. 14.)

Another case was that of A——, wounded May 23rd, 1916, by a shell whilst *squatting on his heels*. A wide transverse sacral wound was found, about 3 cm., and on the right side, ecchymosis of Scarpa's triangle with bubbling sounds on pressure. The abdomen was tense and painful; no micturition; the catheter gave blood and urine without pressure. The *operation* took place at the sixteenth hour. (*A*) In Depage's position (ventral in ∧, legs hanging), vertical incision to enlarge the transverse wound which exactly separated the coccyx and the sacrum; resection of the coccyx; resection of the tip of the sacrum to obtain light. Exploration led to the right side of the rectum, whose mucous membrane remained intact, and into a cavity whose edges were traced and recognised as the *bladder freely perforated;* large siphon drain; then suture of the layers of the rectum, and plugging of the cavity with gauze. (*B*) In the position for laparotomy slightly inverted: (*a*) Exploration of Scarpa's triangle, incision over the ecchymosis at a point where the sounds could be heard; hæmatoma. *The passage of the projectile*

FIG. 19. — Fragments of shell which had penetrated by the sacrum and lodged in the middle of the thigh, after traversing the pelvis at the level of the obturator foramen (Obs. A——, p. 376.

along the femoral vessels was followed: ablation at the middle of the thigh of a *fragment of shell* 6 cm. by 4 cm. (Fig. 19) covered with pieces of clothing; drainage of the passage. (*b*) Exploration towards the pelvis, as small projecting splinters had been found; this led into the *obturator foramen*. (*c*) Supra-pubic incision: *exploratory laparotomy* which showed the peritoneum intact; careful closing of the wound. (*d*) Suprapubic cystotomy; the finger felt a *right lateral perforation low in the bladder:* a large drain was put in the bladder, and another in contact with the bladder and coming out at the root of the thigh.

Death did not ensue until three days later.

It is easy to reconstruct the passage of the projectile; the man being in a squatting position, the fragment entered by the sacrum, traversed the pelvis, and crossed the bladder laterally, passing through the obturator foramen and lightly grazing its edges, then following the sheath of the vessels to stop finally in the middle third of the thigh.

In the case of H——, of which we shall see a more detailed observation on p. 517, a piece of shell had also entered by the groove between the buttocks, and had perforated the rectum, the bladder, and the intestine. After a most eventful operation and complicated sequelæ, H—— recovered completely.

Fractures of the pelvic girdle are particularly harmful: the detached splinters aggravate the visceral lesions; the bones, bathed with septic liquids, rapidly become the prey of destructive infiltration for which nothing can be done.

. . . . .

(5) Associated Abdomino-thoracic Lesions are either Benign or Extremely Serious

The whole evolution of the case is dominated here by the thoracic lesion.

Penetrating wounds of the hypochondria and of the epigastric region are usually so benign that they evolve spontaneously towards recovery. This is also the case when the wounds involve the ninth and even the eighth intercostal space and hence become thoraco-abdominal.

We can, systematically, distinguish *four types*:

(*a*) A blind, penetrating wound, or a rapidly closed tunnel-wound, that has traversed the hypochondrium or the epigastric region, simultaneously involves the ninth, or even the eighth, intercostal space.

It thus becomes abdomino-thoracic, but the thoracic lesions are limited to the pleural cul-de-sac or to the lowest part of the lung. This wound generally maintains the benign qualities of similar wounds in the upper part of the abdomen.

(*b*) With a projectile of the same kind and an abdominal passage equally benign, the more oblique penetrating wound reaches the thorax higher, and causes serious pulmonary lesions. The latter alone dominate the situation.

(*c*) A wound of the upper region of the abdomen, sufficiently serious (hepatic, splenic, or stomachic hæmorrhage, perforation of a colic angle, piercing of the stomach, etc.), sufficiently serious, I say, to necessitate surgical intervention, has also reached the thorax.

It is evident that hæmothorax or hæmopneumothorax of variable gravity will here considerably darken the prognosis; immediately, for anæsthesia is much more dangerous (shock, dyspnœa); and later, for it is in these cases that one observes early or delayed complications of pneumonia with areas of pulmonary breaking-down. (Stern, Caudrelier, Gatelier.)

(*d*) Lastly, we have a wound that establishes a wide communication through the diaphragm and facilitates the hernia of an abdominal viscus, injured or other-

wise, towards the pleura and the lung which may be, involved in various ways (Figs. 20 and 22).

G——, wounded March 7th. 1916, by a bursting shell, had been hit in the left median thoracic region (ninth rib, axillary line).

At the third hour operation on the ninth rib; the omentum was then seen, forming a hernia; resection; in withdrawing it a little to cleanse its neck at the

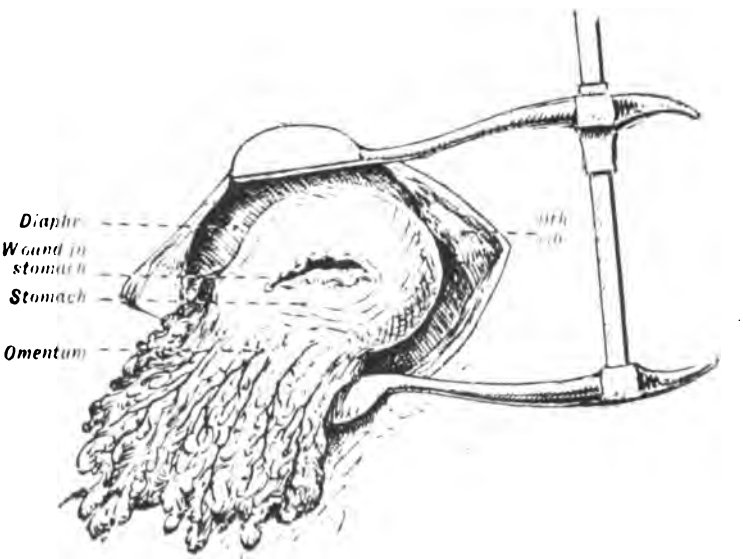


FIG. 20.—Abdomino-thoracic wound with transdiaphragmatic hernia of the perforated stomach and the omentum (Obs. G——, p. 379).

level of the diaphragm, the *stomach* was seen to be also herniated; it showed a *large perforation* of its anterior surface (Fig. 20), near the greater curvature. Suture in two layers was applied to this perforation. The diaphragm was sewn and brought into contact with the parietes and fixed in that position: pleural siphon by an independent drain.

A complementary laparotomy was impossible, on account of the weakness of the patient. He died nine hours afterwards.

Sometimes the single aperture is freely open exteriorly over the splintered ribs, and one can see the lacerated liver grooved or partially broken up, the diaphragm split with widely separated edges, the pleura gaping where the bleeding lung appears and disappears with noisy traumatopnea (Fig. 21).

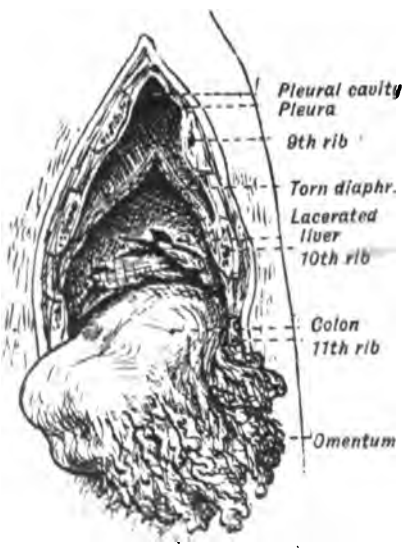


FIG. 21.—Abdomino-thoracic wound with hernia of the omentum, the colon, and the crushed liver; fractures of the ribs; wide rent in the diaphragm. (Case L——, p. 380.)

L——, wounded April 22nd, 1916, showed a large right lateral thoraco-abdominal groove, with wide opening of the pleura above, caused by section of the tenth and eleventh ribs; lower down there were hernia of the colon and of the omentum, and a wound of the crushed hepatic border. Very free hæmorrhage. Patient gasping, pale, and distressed.

A wide opening was made by section of the cutaneous bridge, the edges of the diaphragm, after free resection of the ninth, tenth, and eleventh ribs (Fig. 21), were attached to the muscular borders so that the thoracic cavity above might be isolated; the pleural orifice was reduced to admit only a drain, through which aspiration was conducted, to diminish the total amount of pneumothorax; thus the abdominal cavity was isolated. The herniated parts were cleansed with ether; gauze-wick placed in contact with the bruised liver; drain going towards the abdominal cavity. Closed up on one plane.

The dyspnœa became aggravated. The patient died on the 24th, at ten o'clock.

In this case again it was the thoracic lesion which, even after reparation of the abdominal lesion, remained preponderant, and rendered the prognosis almost necessarily fatal.

There is, therefore, no middle term. Thoraco-abdominal association is either benign, justifying simple abstention, or so serious as to render illusory the benefit of intervention in almost all cases. This double consequence has to be borne in mind.

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RÉSUMÉ.

The synthetic idea that is evolved from the study of anatomical lesions is as follows:

"The essential lesion is not the peritoneal penetration, it is the visceral penetration; and among the visceral lesions it is necessary to distinguish those which create danger from hæmorrhage (the liver, the spleen, and the mesentery), and those which create danger from the effusion of their contents (the intestinal canal). (Quénu.)

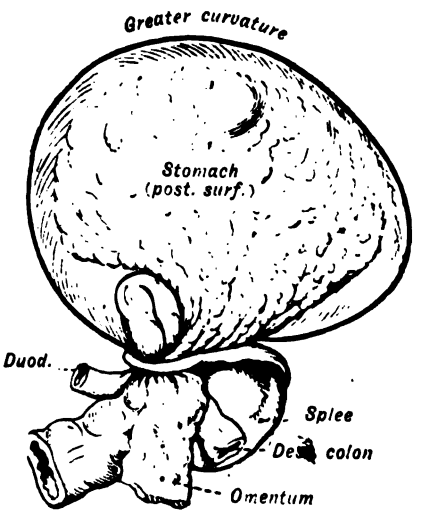


FIG. 22.—Diaphragmatic hernia. View of the organs taken away in the mass with the fibrous diaphragmatic ring. (Legrain, Quénu, Richard [77].)

Looking now at the *topographical distribution* of the lesions, we see that the abdomen may be divided into five regions:

(1) *The umbilical and peri-umbilical region* extend-

ing to the colon externally, and upwards to the stomach. Its lesions affect the small intestine and the transverse colon. These lesions do not heal spontaneously, except in very exceptional cases.

(2) *The hypogastric*, and pelvic region. The lesions involve the small intestine, the sigmoid flexure, the rectum or the bladder. Their chances of spontaneous healing are negligible.

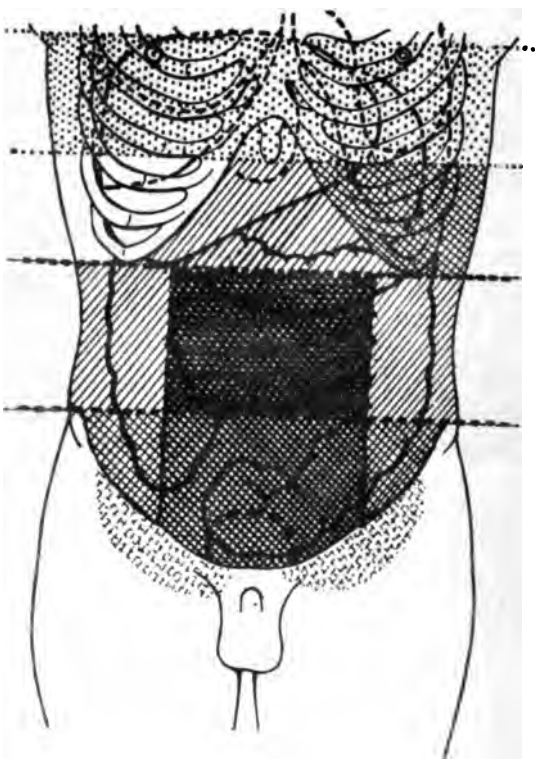


FIG. 23.—Chart of the regions. Topographical distribution of wounds of the abdomen according to their gravity and their variable tendencies towards spontaneous healing. (The lightest region corresponds to a greater benignity, the darkest region to the highest degree of gravity.)

(3) *The flanks*. This is the territory of the ascending and descending colon. The wounds have a chance of healing spontaneously if their entire course is on the same side, antero-posteriorly, and if they are caused by a bullet or very small fragment of shell. An oblique, centripetal course, probably multivisceral, or a large fragment of shell, does not leave much real hope for a favourable termination.

(4) The upper region. Here the wounds affect the

liver, the stomach, or the spleen. Their tendency to spontaneous healing diminishes from right to left; satisfactory and almost invariable as regards the liver, it suffers exceptions in the case of the stomach (when wounded just after eating or when the arterial circle is involved), and is diminished in the case of the spleen by the frequency of hæmorrhages caused by bursting. Lastly, the neighbourhood of the left colic angle, and the anomaly of coils of the small intestine above the transverse colon render wounds near the left hypochondrium still more serious in character.

(5) Higher still, *thoraco-abdominal* association is frequent; being either benign or very serious, these wounds are either liable to heal of themselves or they are beyond surgical help.

And on the adjoining *diagram* (Fig. 23) the regions are made darker in proportion as the spontaneous evolution of penetrating wounds in that quarter affords less chance of healing.*

* If we compare this with Wallace's diagram (Fig. 3), we see that non-visceral penetrating wounds are found appearing precisely in the zones that the above sketch shows to be the most favourable. But a wound of the umbilical region implies an oblique passage through the whole abdominal cavity; it proves the possibility (on which we have already insisted) of a projectile gliding between the coils without injuring them.

CHAPTER V

THE TREATMENT TO ADOPT IS LAPAROTOMY—DISCUSSION

SOME consider that there is not "a" treatment for penetrating wounds of the abdomen, but that the clinical examination of each case ought to guide us, that it is unwise to wish to establish a clear line of demarcation between the interventionists and the abstentionists; that one should not be the slave of an "*à priori* formula."

A slave, no; but *one must in practice have a formula of treatment*, an almost systematic conception of what is nearly always needed for a penetrating wound of the abdomen. One must be impelled to apply a certain treatment in preference to any other: it is an essential condition of rapid decision, prompt execution, and tranquillity of mind. And where the clinical sense intervenes (for that must never lose its authority) is in recognising the *exceptional* cases, those in which one would not apply the chosen treatment, and in recognising the counter-indications to this usual treatment.

The choice to be made is between medical treatment, Murphy's treatment, so-called, and laparotomy.

. . . . .

Murphy's operation, or suprapubic button-hole with pelvic drainage, was proposed by Murphy for the treatment of peritonitis caused by perforation of the small intestine in the neighbourhood of the cæcum, perforation of the cæcum itself, of the duodenum, and

of the stomach. Its object is to drain the abdomen into the dependent part, into the pelvic cavity where we have seen the different intra-abdominal effusions collect by their own weight. It is the "siphonage of a collecting-sink," or simply the escape granted to the "overflow."

Such an operation is rapid, and by no means serious. Local anæsthesia with cocaine is sufficient. In short, it is the type of simple intervention that can be realised everywhere and always.

Is it efficacious?

In favourable cases the pain is eased, the abdominal reaction is alleviated, and the general condition gradually improves. Sometimes it brings about veritable transformations. One of Murard's cases [16], who was extremely weak, in a "dying" condition (but whose pulse was nevertheless 88), made a surprising improvement in a few hours.

At the same time the effusion is lessened, though composed wholly of black blood, it diminishes in abundance, and clears; when fæcaloid it may change into an actual pyo-stercoral fistula, or a fæcal fistula whose spontaneous healing will be indicated by the normal exit of fæces at the anus.

Didier [17] obtained two great successes in two unfavourable cases, and they were really penetrating visceral wounds, as in one of them there was an escape of fæcal matter and in the other of bile.

Even when finally terminating in failure, the supra-pubic button-hole has sometimes brought temporary relief from pain and has calmed the anguish of a wounded man (Murard).

But it is far from being always—or even often so!

"There is unfortunately a shadow in the Murphy picture," writes Tuffier [7]: "they are all cases of effusion of black blood without escape of fæcal matter and followed by death. If in these cases laparotomy

had been performed, and if the real causes of the hæmorrhage had been discovered, a ligature might have put an end to it and consequently saved the wounded man's life!"

One may even ask if in these cases the suprapubic opening confines itself to being inefficacious and does not rather become injurious. Cadenat [16] remarks, not without reason, that when there is simply hæmorrhage this opening diminishes or puts a stop to the abdominal hyperpressure which has come into play to attenuate or arrest hæmorrhages in the closed abdominal cavity; besides that, it brings the chance of exogenous infection to a hæmorrhagic focus hitherto safe from all outside contamination. In short, it may be the cause of death in cases where spontaneous healing might have taken place.

But, above all, we can hardly consider exceptionally efficacious an intervention that ignores the causal lesion; now though the laceration of an empty viscus is of ever such small importance, we have seen that it is anatomically impossible that it should heal locally.

Lastly, even the working of the drainage is uncertain. Murard recommends the following plan: "By introducing a large upright drain into the recto-vesical pouch and placing the wounded man in a sitting position, one can see the blood flow as from a fountain; several days after the intervention we have seen the blood flow as if it came from a tap when we inclined the free end of the drain downwards." Is it constant? Two cases of Chalier's [44] prove that drainage is too often only transitory, and that it is powerless to drain the whole peritoneal cavity, since it did not prevent the rapid development of an enormous subphrenic abscess which carried off both the wounded men in spite of the secondary evacuation. "It is probable," adds Chalier, "that early laparotomy might have disclosed the lesions produced, hindered the formation of the abscess, and brought about recovery." And yet

in one of these cases there was a very marked improvement in the state of the patient, giving rise to the most hopeful expectations for two days—hopes doomed to disappointment!

Besides, look at the summary of the results obtained:

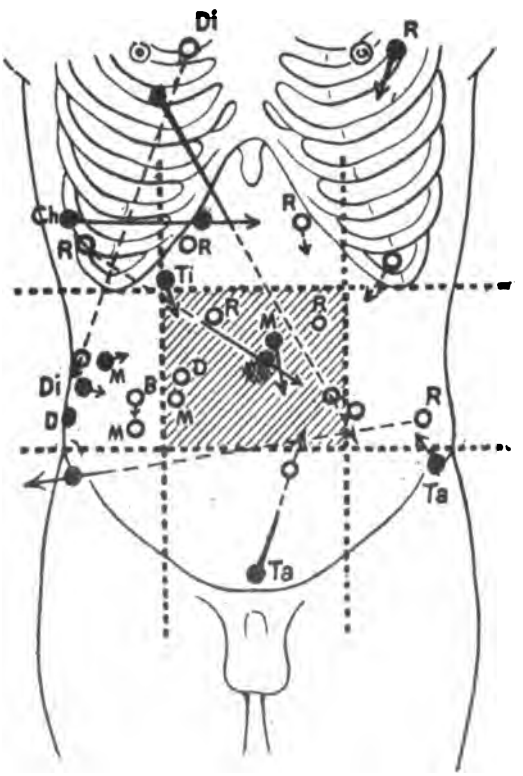
STATISTICS OF THE CASES TREATED BY MURPHY'S OPERATION

Observers.	Total of Cases.	Deaths.	Recoveries.	Observations.
Dupont and Kendirdjy	2	2	—	—
Weiss and Gross	5	5	—	—
Devèze	31	20	11	10 from bullets, 5 cases in which only black blood was seen, 2 cases of lesion of the large intestine; 4 cases of *definite lesion of the small intestine.*
Cadenat	4	3	1	From bullets. Right nipple to left lumbar region; hæmorrhagic fluid, slightly fæcal.
Bichat	4	3	1	From shrapnel bullet.
Pascalis	2	2	—	—
Tartois	15	12	3	One by bullet.
Didier	7	5	2	2 from shrapnel bullet; entry dorsal, exit right flank, bile. 2nd case: right flank, fæcal matter.
Rouvillois	28	23	5	4 thoraco-abdominal wounds; blood only; one wound of descending colon.
Tisserand	2	1	1	Right hypochondrium.
Gorse	15	11	4	—
Chalier	12	10	2	1 from bullet; 2 thoraco-abdominal; blackish blood.
Murard	18	14	4	Shells; 3 right lumbar region or right flank; 1 only para-umbilical: black blood in all cases.
	145	111	34	
	Mortality: 76 %			

We notice here the high rate of mortality. And is even that rigorously exact and sufficiently high? No; the observers themselves object that a number of these wounds were not undoubtedly visceral penetration: in most cases they found nothing more than an

effusion of black blood, without gas or fæcal odour, intestinal débris or fæces.

"Besides," writes Rouvillois [[38]], on the subject of his personal cases (and this remark must be true of several others), "the perusal of the observations shows that they would probably have healed by abstention pure and simple, and that in appropriate surroundings exploratory laparotomy would have been justified. Whatever method had been adopted, they would really have healed in the same way, and their recovery would have been placed to the account of the method." Rouvillois therefore considers that the already high percentage of mortality ought to be increased, and would amount to nearly 100 per cent.



C = Cadenat. *Di* = Didier. *R* = Rouvillois.
Ch = Chalier. *Ta* = Tartois. *B* = Bichat.
D = Devèze. *Ti* = Tisserand. *M* = Murard.

FIG. 24.—Recoveries obtained by the Murphy treatment.* The two para-umbilical wounds only showed an effusion of pure blood. It is interesting to compare this diagram with Fig. 23 (anatomical regions), 3 (no visceral lesions), and 4.

* To these must be added 4 cases from Devèze with ascertained lesions of the small intestine; but we have no note as to their locality.

As to the situation of the wounds healed by the Murphy treatment, it nearly always belongs to the upper region, thoraco-abdominal, or to the hypochondria, the flanks, or the lumbar regions. The adjoining diagram (Fig. 24) which represents them is interesting in comparison with the one in which we have divided the abdomen into regions of different gravity, and also with those of Wallace and Rouvillois, which represent the tracks of the projectiles without visceral lesions (see Figs. 3, 4 and 23).

Only two of the wounds were para-umbilical, and both only gave rise to effusions of pure blood through the orifice of drainage.

In short, insufficient in serious cases, useless in slight cases, and sometimes harmful—such we find the Murphy treatment, of which it has been well observed that " the wounded have recovered in spite of it, and not thanks to it ! " (Weiss and Gross.)

Fallen into deserved discredit, abandoned even by those who had shown themselves its partisans, the suprapubic button-hole merits only to be retained for penetrating abdominal wounds seen too late to be treated by laparotomy, or for cases treated by abstention and in which a hypogastric, iliac, or pelvic localisation of the subsequent peritonitis is manifested.

From the point of view of immediate treatment we have only mentioned it in order to eliminate it.

The same might be said of a method defended by Miramond de la Roquette [84]. This consists of a completion of the Murphy treatment by the opening of an **iliac anus** which " ensures the drainage of the intestine, and prevents the phenomena of intestinal paresis, so frequent and so formidable." This description is indefinite. Is it a question of deliberately opening in the iliac fossa the first loop that presents itself, whether healthy or not ? Or is it a question of making a wide opening in the skin, but at the level

of the parietal wound, of the perforated coil of the small intestine supposed to lie nearest to it, in which case the coil will not always be iliac ? . . . In either case the end proposed will not be reached. The intestinal paresis is caused by the peritonitis; the effect of the latter is the arrest of all contraction, and hence the stoppage of the evacuations and the distension of the gut. Operations on cases of peritonitis with distended intestines suffice to assure us that all intestinal drainage is nugatory; the loop operated on empties itself—the others, even those nearest, remain as inert as before. And if, as Miramond has observed, recovery has supervened in several cases after spontaneous fistulisation, this did not happen because the intestine was not under tension, but because its contents did not make an irruption into the peritoneum; it was not because the intestinal liquid ran "outside," but because "it did not run inside."

Sencert has proposed a **triple drainage** in the hypogastric region and in each of the iliac cavities; he reserves it for the hopeless cases, and therefore this intervention, he says, requires no "counter-indication." That is true, but neither does it afford "indication." If the case is hopeless, it is useless to disturb him; if any chances of success remain, laparotomy will bring them all into action. In the absence of demonstrative cases one cannot retain this method of treatment except in exceptional cases. This, moreover, would accord with the views of Sencert himself, as he does not profess to make it an habitual method of immediate treatment.

. . . . . .

Hence the choice to be made rests between MEDICAL TREATMENT and TREATMENT BY LAPAROTOMY. "Should one operate on those wounded in the abdomen, or leave them to the healing powers of nature. There is the crux." (Quénu.)

The arguments in favour of each method occur to

the mind so naturally that there is hardly any need to enumerate them.

Medical treatment represents the maximum of simplicity; it is applicable everywhere, with one reservation—the wounded must be kept motionless, and there must be no premature discharge from hospital in their case. Applying equally to all cases, from wounds simply suspected of penetration to the most extensive shattering (unless, like Sencert, one has recourse to surgery because there is no risk of doing more harm than good), the abstentionist method dispenses with all subtlety of diagnosis and prognosis. No special competence is necessary; no complicated installation is required; the superintendence of the nursing is as easy as it is imperative in its precepts; the control of the surgeon himself need be neither immediate nor assiduous. In short, it is the ideal of the "pass-key" treatment.

Laparotomy, on the other hand, offers in all these aspects as many drawbacks as abstention afforded advantages. To compensate for all these strong arguments against it, we have only one to bring forward in its favour—laparotomy addresses itself to the cause! It is not "palliative" of peritonitis or of hæmorrhage; it is prophylactic of peritonitis and a corrective of hæmorrhage. It is not blind: it searches out the visceral lacerations themselves and repairs them straightway; it ties up the bleeding vessel. Lastly, and chiefly, it is capable of repairing serious lesions against which the healing power of nature is obviously powerless.

And these advantages are of such force that, after triumphing over all resistance and allowing of the establishment of a therapeutic dogma in time of peace, we have seen them, in spite of the experiences of former wars, reaffirmed in the present war.

And what is more forcible than arguments, it will be observed, is the total of results obtained by both methods, which must be compared!

I.—STATISTICS OF THE CASES TREATED BY ABSTENTION

Observers.	No.	Deaths.	Recoveries.	Observations relating to Cases of Recovery.
Dupont and Kendirdjy	38	38	—	—
Sencert	58	45	13	13 bullets: 6 cases, abdominal reaction slight or absent; penetration possible; 7 cases, visceral penetration very improbable.
Weiss and Gross	57	49	8	—
Schwartz	10	7	3	3 bullets: 2 in upper region of abdomen; 1 lateral wound of left colon.
Chavannaz	38	22	16	Regarding the 22 cases, 20 deaths if one counts only the cases where penetration certain.
Gosset	5	5	0	3 died from slow peritonitis on the fourth day; they might perhaps have benefited by intervention.
Cadenat	9	3	6	1 case only where one might admit undoubted wound of the large intestine, probably extraperitoneal.
Bichat (I)	13	8	5	5 bullets: 1 not penetrating, 4 wounds of the large intestine.
Bichat (II)	8	8	0	—
Pascalis	10	7	3	3 bullets: 2 wounds of the hypochondria; 1 wound of the flank.
Pellot	12	6	6	—
Tartois	8	8	0	—
Marquis	68	36	32	21 bullets: the author says, "a number were probably not penetrating"; 6 intestinal hernias; 2 recoveries.
Barbet and Bouvet	11	10	1	Penetration doubtful. In a former period these authors had seen numerous cases, all deaths.
Didier	3	—	3	1 in upper abdominal region, 1 simple penetrating wound, 1 wound of the colon.
Gatelier	12	12	0	—
R. Picqué	16	14	2	—
Stern	50	46	4	1 bullet: all with fæcal fistula; 2 wounds of the large intestine, perhaps extraperitoneal.
Rouvillois	—	—	A certain number of recoveries, but no precise figures	—
Simonin	17	16	1	—
Delore	More than 100	All	—	—

Cotte and Latarjet	5	5	0	
Vignard	11	2	9	6 wounds of the upper region; 3 of the region of the large intestine with fæcal fistula.
Gaudier	75	72	3	
Quénu	20	4	16	9 had to be operated on afterwards; 7 simple penetrations, of which 6 with omental evisceration had to be operated on; 6 visceral wounds, of which 3, of the liver, were slight, 1 doubtful of the stomach, 2 of the large intestine, right flank, ileopelvic loop of intestine eviscerated and perforated.
	656	525	131	
	Mortality: 80·2 %			
Chevassu	97	30	67	9 eviscerations, 8 deaths; 9 stomach, 0 death; 20 liver, 2 deaths; 12 kidney, 3 deaths; 2 bladder, 1 death; 1 spleen, 1 death; 2 great intestine, 0 death; 32 small intestine, 6 deaths; 10 indeterminate, 9 deaths.
Chevassu, modified by Tuffier	78	23	59	5 eviscerations, 4 deaths; 7 stomach, 0 death; 11 liver, 2 deaths; 12 kidney, 1 death; 2 bladder, 1 death; 1 spleen, 1 death; 19 peritoneum, 0 death; 1 large intestine, 0 death; 10 small intestine, 5 deaths; 10 indeterminate, 9 deaths.
Chevassu, modified by Quénu	57	25	32	5 eviscerations, 4 deaths; 8 stomach, 0 death; 12 liver, 2 deaths; 12 kidney, 1 death; 2 bladder, 1 death; 1 spleen, 1 death; 8 small intestine, 6 deaths; 9 indeterminate, 9 deaths.
With Chevassu's figures	753	555	198	
	Mortality: 74 %			
With Chevassu's figures, modified by Quénu	713	550	163	
	Mortality: 77·2 %			

II.—COMPLETE STATISTICS OF THE CASES TREATED BY LAPAROTOMY

	Total of the Laparotomies.		Laparotomies with lesion of the Small Intestine.	
	No. of Cases.	No. of Cures.	No. of Cases.	No. of Cures.
Chirurgical Society :				
Sencert	4	—	2	0
Weiss and Gross	4	—	—	—
Cadenat	14	2	14	2
Dupont and Kendirdjy	4	1	3	1
Chavannaz	13	4	—	—
Gosset	7	4	3	2
Vertraeghe	11	3	?	1
Schwartz	9	2	8	2
Bouvier and Caudrelier (I)	32	15	18	6
Duter and Hallez	1	1	—	—
Goinard	1	1	1	1
Charrier	1	1	—	—
Petit	2	2	—	—
Bichat	20	7	8	1
Pelot	11	10	—	—
Pascalis	3	3	1	1
Bouvier and Caudrelier (II)	65	35	21	10
Tartois	11	5	4	4
Schwartz and Mocquot	46	16	15	5
Mathieu	26	6	13	1
Stern	34	14	16	3
Rouhier	2	1	2	1
Barbet and Bouvet	15	7	5	3
Didier	10	4	3	1
Gatelier	11	5	5	1
Proust	101	15	?	7
Abadie	15	6	12	3
Picqué	15	6	4	2
Rouvillois	74	20	40	8
Simonin	20	8	6	1
Abadie (not yet published)	17	5	8	2
Outside the Chirurgical Society :				
Leriche	4	2	2	—
Cotte and Latarjet	7	4	2	2
Tisserand	7	3	4	1
Chalier	2	—	1	—
Delay and Lucas-Championnière	22	11	10	4
Gaudier	14	9	?	?
Sejournet	10	3	?	?
Clermont	18	7	15	6
Carpanetti	2	1	2	1
Murard	3	—	3	—
Total	688	249	251	75
	Recoveries : 36 % Mortality : 64 %		Recoveries : 30 % Mortality : 70 %	

This is just the delicate point. Nothing appears simpler than to oppose statistics to statistics, but the figures themselves have to be strictly scrutinised to have any value as regards comparison.

. . . . .

Here are the figures. They are presented in three tables, which include the greatest possible number of published cases in order that the percentages may be the more accurate, and that the observations recorded by the different observers may balance each other.

The first table gives the results obtained by operative abstention and medical treatment; we have added to the figures some observations, in the cases of recovery only, relating to the nature of the projectile, to the seat of the lesions, to some symptomatic peculiarities, etc., and these remarks will have their value a little later on.

The second table gives the whole of the results furnished by laparotomy, while a parallel set of statistics concerns only the cases in which the small intestine was involved alone or with other organs.

The third table enters into more detail on the subject of the laparotomies; it classifies the cases according to the situation and the gravity of the anatomical lesions, and therefore allows of the formation of a prognostic percentage according to the lesions observed; a column is also reserved for the nature of the projectile.

From the comparison of these tables a marked contrast appears:

Abstention has a mortality of from 75 to 80 per cent.;

Laparotomy has a mortality of 64 per cent.

The advantage is, therefore, seen to be on the side of laparotomy.

But one could not accord absolute certainty to these figures. They are open to criticism, the result of which is still more favourable to laparotomy.

III.—DETAILED RESULTS OF LAPAROTOMY IN WOUNDS OF THE ABDOMEN

Authors.	Total number of cases laparotomised.	Non-Penetrating.				Penetrating.														Nature of the Projectile.			
		Parietal.		Visceral and of large vessels.		Simple.		Univisceral.								Multivisceral.						Thoraco-abdominal.		Bullets.		Shells.		Bombs, petards, etc.	
								Intestine.		Stomach.		Colon.		Liver, gall-bladder.		Kidney and urinary organs.		Spleen.		Small and Large Intestine.		Colon and viscera other than small Intestine.		Small Intestine and viscera except colon.		Viscera except colon and small Intestine.							
—		C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.
Sencert	4	—	—	—	—	1	1	1	1	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	1	1	3	0					—	—
Weiss and Gross	4	In 66 cases, the lesions were 56 times in the intestines, especially the small intestine.																															
Cadenat	14	1	0	—	—	—	—	12	10	1	0																								
Dupont & Kendirdjy	4	—	—	—	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	—	—	4	3				
Chavannaz	13	—	—	—	—	1	0	1	1	—	—	7	4	1	1	—	—	—	—	—	—	1	1	—	—	—	—	2	2	5	1	4	2		
Gosset	7	—	—	—	—	—	—	1	0	—	—	1	0	—	—	—	—	—	—	1	1	1	0	1	0	—	—	2	2	7	4				
Vertraeghe	11	No case-observations other than those of recovery.																															
Schwartz	9	—	—	—	—	—	—	8	6	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	3	—	6			
Bouvier & Caudrelier	32	1	9	3	2	1	1	15	10	—	—	4	1	5	1	—	—	—	—	2	1	—	—	—	—	1	1	1	1	12	8	13			
Duter & Hallez	1	—	—	—	—	1	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1				
Goinard	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1					
Charrier	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	1	1		
Petit	2	—	—	—	—	—	—	—	—	—	—	1	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1				
Bichat	20	—	—	—	—	2	—	5	5	—	—	2	0	2	0	—	—	—	—	1	1	2	2	2	1	1	1	1	1	7	1	9	4		
Pellot	11	—	—	—	—	2	1	5	5	1	1	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	0	4	0	4	1

| | | |

Is it not surprising to see attributed to the same therapeutic method, abstention, such different rates of mortality as these? Reduced to 18 per cent. by Chevassu, the amount is 33 per cent. for Cadenat, 58 per cent. for Chavannaz, 86 per cent. for Gross and Weiss, and 100 per cent. for Dupont and Kendirdjy, Delore, etc.

The reason is that into the cases treated by abstention many incongruous, uncertain facts enter; with "true abdominals," the result of wounds at least penetrating, if not visceral, are mingled the "false abdominals," where only the abdominal wall has been involved, and where the organs have been injured without the peritoneum having been traversed or affected at all.

How, in fact, in the greater number of cases, has the penetration been established? From the supposed or verifiable passage of the projectile, from the situation of this projectile as shown by the X-rays, or from the symptoms of peritoneal reaction. Now we shall see in the chapter on diagnosis how frequent are the causes of error leading to the conclusion that a visceral penetration exists, when in fact it does not exist; and thus many cases resulting favourably come to swell the statistics of abstention.

This is so true that certain authors, like Marquis, are careful to point out themselves that many of the recoveries they register very probably concern wounds that were evidently abdominal, but not in the least penetrating. Chavannaz himself reduces his initial figures of 38 cases with 16 recoveries, to 22 cases with 2 recoveries, if they are limited to those in which penetration was absolutely certain.

Equally striking is the difference so frequently remarked between the figures presented by the observers and those retained, after close scrutiny of the observations, by the reporters. Nothing is more typical than these two facts—97 of Chevassu's cases are brought down to 78 by Tuffier, and 57 by Quénu!

and, more especially, 32 cases of wounds of the small intestine cited by Chevassu with 26 recoveries are reduced, after discussion, to 8 cases with 2 recoveries with fæcal fistula!

But here is another proof still more convincing. Quénu [51] thought that the treatment of abdominal wounds could be judged by its results shown in the evacuated cases in the zone of the interior. "I have been able," he says, "to observe carefully 62 men wounded in the abdomen of whom only 9 had been operated on in the ambulances at the front. It seemed at first to be a triumph for abstention, but the triumph was only apparent." In reality, of the 53 evacuated without operation, 28 had been suffering from non-penetrating wounds, and yet their labels bore the diagnosis of perforating wounds in half the cases.

"In five other cases penetration was doubtful; thus the number of undoubted abdominal wounds was reduced to 20. But amongst these 20 patients have to be counted those who were lost a few days after arrival or even on the way; I notice four cases of this kind. Of the 16 remaining, three wounded had to be operated on immediately or in a few days; this reduces the number of penetrating wounds to 13. These 13 cases are classed as follows: 7 simple penetrating wounds, that is to say without visceral lesions, and 6 visceral penetrating wounds. Of the 7 simple penetrating wounds 4 were complicated with omental evisceration; these had to be operated on, and it would certainly have been better, if possible, to operate at once."

"The visceral wounds not operated on include three wounds of the liver, one supposed wound of the stomach, and two wounds of the large intestine.

"Of the three wounds of the liver, one gave rise ultimately to an abscess in the lumbar region. Of the two others occasioned by bullets, one was not at all deep, for the projectile felt at the end of the probe

was extracted simply by the enlargement of the track and neither had given given rise to hæmorrhage of any importance, and seemed to have taken their course at some distance from the hilum."

"Lastly, of the two wounds of the large intestine, one had its track in the right flank with the two orifices not far from each other, and the other affected the ileo-pelvic loop; when the patient was carried to the ambulance this loop was eviscerated and perforated. One might regard this as a favourable circumstance, and consider that the traumatism had itself performed the operation, so to speak, by placing the perforation in communication with the exterior. Abstention was not complete, either, as soon after, at the ambulance, the result had to be completed by the resection of the gangrenous and herniated loop.

"In short, as regards visceral wounds, the good results given by abstention are limited to one supposed wound of the stomach, to three wounds of the liver of small importance, and to two wounds of the large intestine on the particulars of which I have enlarged." (Quénu.)

And if one considers that the massed official statistics of the medical service can be used as a basis of appreciation, we see how much these remarks of Quénu's deserve to be dwelt on! It might even occur to one to contrast two sets of figures—those of the wounded who recovered, and those of the recoveries of the men not operated on, who arrived at the base. Now the number of units where operations are performed is much smaller than that of the ambulances where abstention is practised; therefore the total number of those operated on is very inferior to that of the non-operated. But again, among the non-operated are unfairly included, as suffering from penetrating wounds, many who were not so wounded; and many were counted as not operated on who would have to undergo an operation later on.

And *abstention alone benefits by all these errors of diagnosis*; on the other hand, they are placed to the debit account of intervention, which is reproached for its exploratory laparotomies!

The partisans of medical treatment also maintain that a very large number of seriously wounded whom no treatment would be able to save from an inevitable and speedy death are forcibly counted in the lists of abstention, and unduly darken its statistics. No doubt, but the same thing happens to the results of those who, like Caudrelier and Bouvier, Schwartz and Mocquot, Mathieu, etc., have tried to maintain an exact balance, and have systematically operated on *all* the wounded brought to them.*

It would seem logical, therefore, to eliminate such cases from both statistics; but how would it be possible to eliminate the desperate cases without being arbitrary?

And there is another cause that detracts from the absolute value of the figures. A formation close to the front will receive a great number of desperate cases, whereas a more distant ambulance will not—they will have died on the spot or during removal.

There is also another fact to be considered. In a period of intense fighting, the wounded are gathered in more slowly; numbers of the most serious cases do not reach the sanitary formation. On the other hand, in calmer intervals nearly all those wounded in the abdomen have time to be taken to the ambulance, and the surgeons, not being over-driven, are able to make the most of their chances, even the slightest. Operative losses mount up in consequence. So many more deaths will occur, that a more rigorous

* In Bouvier's second series, for instance, no less than 15 very serious cases are counted in which, the abdomen being full of blood or fæcal matter, death supervened in the few hours following the operation, or—it must in justice be added—their arrival at the ambulance.

selection would have driven back into the failures of abstention!

What can we conclude, after enunciating so many necessary corrections, but that *a mere contrast of statistics is vain and without any real signification?*

. . . .

We have also thought out another mode of comparison, and here are the terms in which we have described it to the Chirurgical Society on March 1st, 1916:

"*However paradoxical it may appear, it is only the cases operated on that allow us to estimate the value not only of surgical, but also of medical treatment.*"

We could not, in fact, compare the statistics given as assets of either method. The figures furnished for cases operated on have alone an exact value: only the cases operated on furnish, first, the proof of penetration, and, secondly, the control of the lesions.

What we can deduce from the statistics of abstention, or rather from certain well-observed facts, is the possibility of recovery by abstention.

On the other hand, we have sufficiently exact anatomical data to know what lesions are capable of spontaneous recovery, without direct surgical interference.*

The analysis of the cases operated on will therefore allow, according to the lesions observed, of separating

* Quénu, at the meeting on April 5th, confirmed our point of view by saying: "I believe we ought to proceed otherwise: we ought to reason with what general pathology and our clinical experience have taught us. We are allowed to believe that when an important vessel bleeds, even if there exists some chance of spontaneous hæmostasis, the surest plan is to tie the vessel; we have reason to suppose that fragments of clothing, of earth, of projectiles, above all of fæcal matter, are injurious when in contact with the peritoneum.

"We persist in believing that the non-punctiform perforations of the small intestine can only heal by being sutured, and that, as to the punctiform perforations, they precisely answer to the favourable cases, or those which most certainly benefit by intervention.

and contrasting, with supporting figures, those cases which offered no chance of recovery without operation, and those which might . . . perhaps . . . recover by abstention. And one can see how much such a classification would be advantageous to abstention: all the benefit of the doubt, when doubt exists, goes to abstention.

To press the question more closely, we can even separate the cases operated on into three categories:

Category A.—Wounded who, without laparotomy, would *certainly have recovered* (from their abdominal lesions, obviously). That is to say: laparotomy useless, perhaps injurious.

Category B.—Wounded who, without laparotomy, would *perhaps have recovered.* That is to say: laparotomy perhaps useless.

Category C.—Wounded who, without laparotomy, *would certainly have died.* That is to say: laparotomy necessary or powerless.

In accordance with this classification, I have taken all the observations published at the Chirurgical Society in which the description of lesions is sufficiently exact to allow of an opinion on the possibilities of spontaneous healing, with the endeavour, in doubtful cases, always to give medical treatment the advantage, that is, to favour Category B. I thus arrive at the following figures.*

I would therefore establish the balance in another way: I would put on one side the cases in which laparotomy has furnished few or no indications, where it has been only or almost entirely exploratory, and I would note the losses imputable to the operation or to the anæsthesia. I would place on the other side the cases in which the ligature of an artery, a necessary plugging, the removal of great pollution, and the obliteration of perforations have more than justified intervention, and I would note the number of lives saved.

"The balance, between the victims of the first series and the 'escapes' of the latter, appears to me to give the equitable solution."

How well these lines of Quénu's corroborate the point of view that we advocated ourselves in one of the preceding meetings!

* Here is the classification of the control cases:

Sencert: (C) Obs. 26, 37, 56.
Dupont and Kendirdjy: (C) Obs. 2, 3, 4.
Chavannaz: (B) Obs. 9, 10, 11; (C) Obs. 1, 2, 3, 5, 6, 8, 12, 13.
Gosset: (B) Obs. 2, 6, 7; (C) Obs. 1, 3, 4, 5.
Vertraeghe: (B) Obs. 1; (C) Obs. 1, 2, 8, observations in which "grave lesions," not specified, existed.
Schwartz: (B) Obs. 8; (C) Obs. 1, 2, 3, 4, 5, 6, 7, 9.
Bouvier and Caudrelier: (A) Obs. 11, 31; (B) Obs. 1, 14, 18, 19, 29, 32, 33; (C) Obs. 2, 3, 4, 5, 6, 7, 8('), 9, 10, 12, 13, 15, 16, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30.
Goinard: (C) Obs. 1.
Duter and Ballez: (B) Obs. 1.
Petit: (B) Obs. 1; (C) Obs. 2.
Bichat: (B) Obs. 5″, 6″, 5‴, 10‴, 12‴, 13‴; (C) Obs. 1, 2, 3, 1″, 2″, 1‴, 2‴, 3‴, 4‴, 6‴, 7‴, 8‴, 9‴, 11‴.
Pascales: (B) Obs. 2, 3; (B) Obs. 1.
Bouvier and Caudrelier: (A) Obs. 1–7, 13, 40; (B) Obs. 8–12, 16, 23, 28, 29, 30, 31, 35, 36; (C) Obs. 14, 15, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 32, 33, 34, 37, 38, 39, 41–65.
Tartois: (C) The eleven observations of the series.
Schwartz and Mocquot: (A) Obs. 7, 16, 17, 10″; (B) Obs. 4, 9, 14, 20, 22, 1″, 6″, 12″, 15″, 20″; (C) Obs. 1, 2, 3, 5, 6, 8, 10, 11, 12, 13, 15, 18, 19, 21, 23, 24, 2″, 3″, 4″, 5″, 6″, 8″, 9″, 11″, 14″, 16″, 17″, 18″, 19″, 22″.
Mathieu: (B) Obs. 1, 15, 18, 26; (C) 2, 3, 4, 5, 6, 7, 8′, 9, 10, 11, 12, 13′, 14, 16, 17, 19–25′.
Stern: (B) Obs. 1, 2, 3, 4, 20, 21, 27; (C) Obs. 5, 6, 7, 8, 9′, 10–19, 22–26, 28–34.
Rouhier: (C) Obs. 1, 2.
Barbet and Bouvet: (A) Obs. 18; (B) Obs. 20, 22, 26; (C) Obs. 13, 14, 15, 16, 17, 19, 21, 23, 24, 25.
Didier: (C) Obs. 1–8.
Gatelier: (A) Obs. 2; (B) Obs. 5; (C) Obs. 1, 3, 4, 6–11.
Abadie: (A) Obs. 1; (B) Obs. 2; (C) Obs. 3–5′, 6–15.
Rouvillois: (A) Obs. 10, 11, 13; (B) 37–43, 45–52, 80; (C) Obs. 44, 47–49, 53–105, 121, 123, 124 (numbers of these interventions relate to almost dying cases).
Simonin: (A) Obs. 1; (B) Obs. 2, 3, 4, 10, 12; (C) Obs. 5–9, 11, 13–20.
Tisserand: (B) Obs. 5; (C) Obs. 3, 4, 8, 9, 10, 11.
Cotte and Latarjet: (B Obs. 9, 15; (C) Obs. 4, 5, 8, 13, 14.
Delay and Lucas-Championnière: (A) Obs. 2, 16; (B) Obs. 9, 17, 18; (C) Obs. 3–8, 10, 11, 13, 14, 15, 19–22.
Murard: (B) Obs. 3; (C) Obs. 1, 2.

The observations marked with a (′) concern the manifestly hopeless cases, operated on chiefly in order to apply intervention without exception in every case, to have complete statistics, or to cases in which the surgeon himself declares that he will not operate again on such apparently dying cases. We count them, nevertheless, to avoid all subtlety of discussion and to arrive at a distinct formula.

—	Laparotomy useless, perhaps injurious. *A.*		Laparotomy may be useless. *B.*		Laparotomy necessary or powerless. *C.*	
	No. of Cases.	Recoveries.	No. of Cases.	Recoveries.	No. of Cases.	Recoveries.
Sencert	—	—	—	—	3	—
Dupont and Kendirdjy	—	—	—	—	4	1
Chavannaz	—	—	3	3	8	—
Gosset	—	—	3	3	4	1
Vertraeghe	—	—	1	1	10	2
Schwartz	—	—	1	1	8	2
Bouvier & Caudrelier (I)	2	2	7	7	23	7
Goinard	—	—	—	—	1	1
Duter and Hallez	—	—	1	1	—	—
Petit	—	—	1	1	1	1
Bichat	—	—	6	6	14	3
Pascalis	—	—	2	2	1	1
Pellot	—	—	—	—	7	—
Bouvier & Caudrelier (II)	9	9	13	13	43	13
Tartois	—	—	—	—	11	5
Schwartz & Mocquot	4	3	10	10	13	4
Mathieu	—	—	4	4	32	2
Stern	—	—	7	6	27	8
Bouhier	—	—	—	—	2	1
Barbet and Bouvet	1	1	3	3	10	4
Didier	—	—	—	—	8	2
Gatelier	1	—	1	1	9	4
Abadie	1	1	1	—	13	4
Rouvillois	3	3	13	12	58	7
Simonin	1	1	5	5	14	2
Abadie (not published)	—	—	2	1	15	4
Cotte and Latarjet	—	—	2	2	5	2
Tisserand	—	—	1	1	6	2
Chalier	—	—	—	—	2	—
Delay and Lucas-Championnière	2	2	3	3	15	5
Murard	—	—	1	—	2	—
	24	22	91	87	367	89

We complete this table to-day by adding all the cases since published at the Chirurgical Society, or that we have found sufficiently detailed in other publications.

Before drawing conclusions from the foregoing, we must specify the cause of the three deaths that we find in the categories A and B:

(A) The death of one of Schwartz and Mocquot's wounded (Obs. 17) was caused on the day following the operation by pneumothorax, dyspnœa, and asphyxia, for which neither the laparotomy itself nor the anæsthesia could be held answerable.

Gatelier's patient (Obs. 3) had a thoraco-abdominal

association; he died on the 31st day from hepatisation of the right lower lobe, and from gangrene of the pulmonary tissue. Laparotomy had nothing to do with this, and if anæsthesia by ether can be suspected of aggravating the pulmonary complication, that is an argument for rejecting ether, but not against laparotomy.

(B) The same remark applies to Stern's patient (Obs. 1) who was placed under a window always kept open, who got up, and died from pneumonia on the following day.

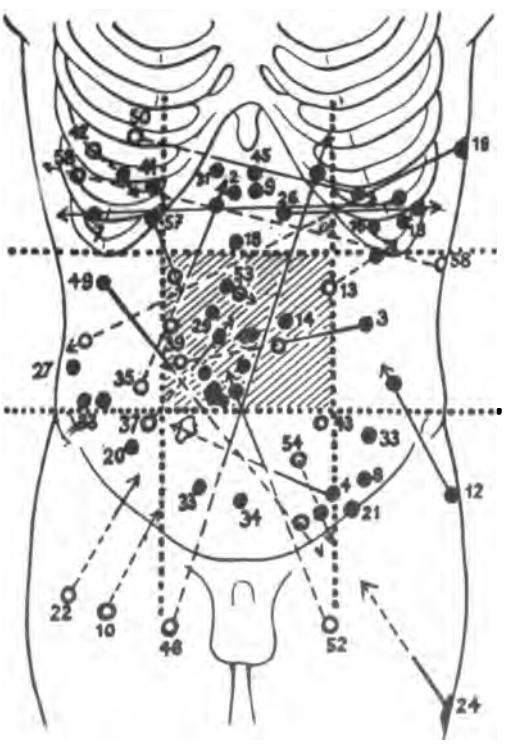


FIG. 25.—Deaths by abstention. Sencert [2]. To compare with the preceding figure.

The case of Rouvillois (Obs. 80) lends itself to discussion, but the fact of our placing it in category B proves that we admit the possibility of spontaneous healing. It was a case of an abundant hæmoperitoneum caused by a wide laceration of the anterior border of the liver, extending from the vesicular notch to the falciform ligament; a fragment of the liver as large as two thumbs was almost entirely detached; there was also a wide perforation of the gall-bladder, and a second wound 5 cm. long in the inferior surface of

the right lobe of the liver. The sutures only held partially. Death on the fourth day was caused by a well-localised focus of sub-hepatic peritonitis. Considering the good general condition of the patient, before intervention (Pulse 64), and the diminution of pain, is it possible that he might have recovered, in spite of the blood in the peritoneum and the bile in the peritoneum ? Still, intervention does not appear to have caused the peritonitis, as the latter remained localised to the liver, without spreading to the rest of the peritoneal cavity when the explorations were extended to the latter. One conclusion to be drawn from this case is that it is advisable to be more cautious in making surgical intervention in the region of the liver.

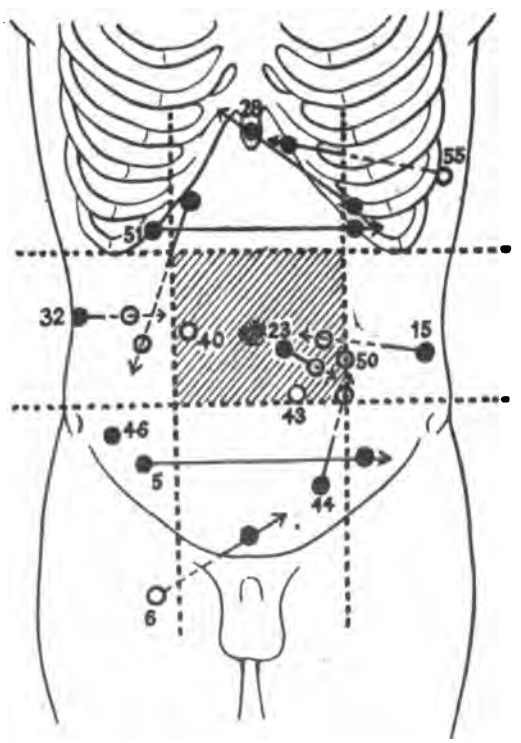
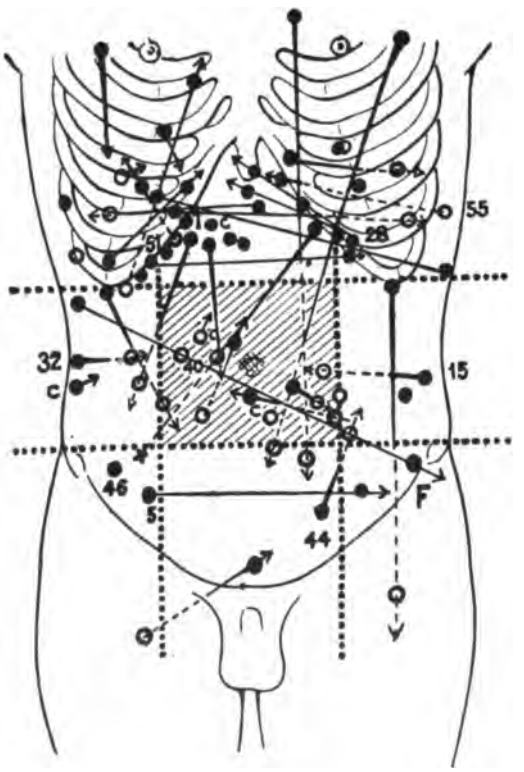


FIG. 26.—Recoveries by abstention. Sencert [2]. To compare with the following figure.

The same conclusion as regards the colon is drawn from our own unfortunate case (see its case-report on p. 488). A lateral wound of the ascending colon, a tunnel-wound caused by a bullet, with very localised reaction, was treated by lateral laparotomy ; we found the rent in the middle of a sanguineous infiltration of

the meso-colon; at that very moment intestinal contents escaped. The patient died of peritonitis, which perhaps would not have occurred without intervention, as the closure of the laceration seemed established. In any case, a mistake of operative procedure had been made; before the laparotomy, as the passage was so lateral, and the intra-peritoneal penetration of the colon was not certain, I ought to have explored the course of the wound and confined myself to a free opening-up of the extra-peritoneal focus: we are well aware of the difficulty and the uncertainty of extra-peritoneal sutures of the large intestine!



F. Fæcal Fistula.

FIG. 27.—Recoveries by abstention, obtained from a total of 121 cases of Sencert, Cadenat, and Chevassu (retaining only the penetrating wounds admitted by Tuffier and Quénu). Of the three wounds in the umbilical zone, two were accompanied by no reaction, and the third gave rise to a fæcal fistula. This diagram should be compared with the following figure.

From the cases that I have just collected and analysed it results: (1) That the wounded who, without laparotomy, would *certainly have recovered*

from their abdominal lesions, recover also in spite of laparotomy;

(2) The wounded who, without laparotomy, might *perhaps have recovered*, will almost certainly recover with laparotomy;

(3) Of the wounded who, without laparotomy, would *certainly have died*, a considerable proportion recover in consequence of laparotomy; that proportion is here 25%.

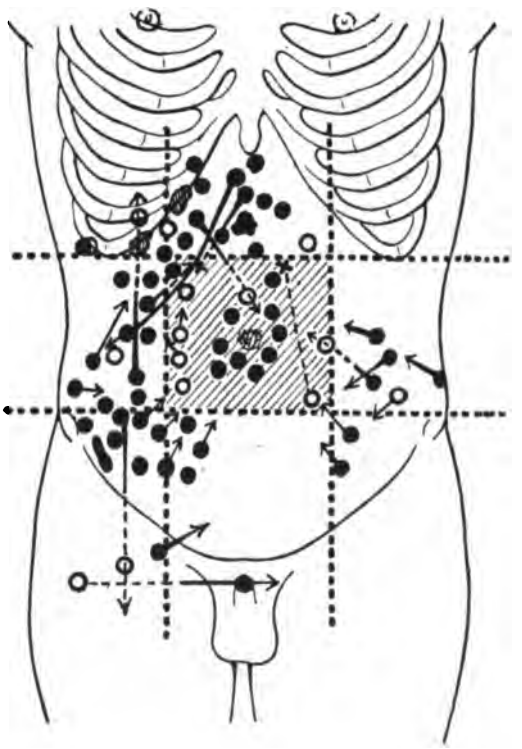


FIG. 28.—Recoveries by laparotomy drawn from a total of 125 penetrating wounds of Bouvier and Caudrelier, Schwartz and Mocquot. We see that they include recoveries from wounds of the umbilical region. This diagram should be compared with the preceding, Fig. 27.

To put it somewhat roughly, and in extreme terms: "If we are mistaken, we do not kill any one; when we operate on the condemned, we save a quarter of them!"

Therefore (and bearing in mind that, so far, we do not see any possibility of its practical realisation), *the preferable treatment of penetrating abdominal wounds is laparotomy.*

. . . . . .

Are there not cases in which this treatment

should or may be discarded, or should or may be deferred?

No doubt there are. And we shall logically return to this in the chapter on diagnosis, in discussing therapeutic indications.

But these exceptions to the general rule evolve so naturally from the observation of the recoveries left to the credit of abstention, that we must discuss them now. First, here are two diagrams (Figs. 25 and 26); they represent, *for the same observer and the same method* (medical treatment), in one the deaths and in the other the recoveries. We see the relative rarity of the latter, and in what regions of the abdomen they are situated. Only one wound is found situated in the umbilical zone; the notes state that only a slight abdominal reaction was found (Obs. 23); it is therefore probable that it was an example of one of those wounds that we have mentioned, where the projectile glides between the coils without perforating them.

Two other diagrams (Figs. 27 and 28) compare the *recoveries obtained on the one hand by abstention, on the other by laparotomy.* Both concern a number of almost similar cases: 121 in the first instance (Sencert 58, Cadenat 11, Chevassu 52), 125 in the second (Bouvier and Caudrelier 84, not counting the parietal wounds, Schwartz and Mocquot 41).

With regard to abstention, we should note the frequency of recovery in lumbar wounds (of which the peritoneal or visceral penetration is far from being always proved), and in wounds of the upper region. In the umbilical zone, we have already noted the slight reaction presented by Sencert's patient (Obs. 23); it is the same with Catenat's patient (Obs. 1, right subumbilical opening.) The two wounds marked F, in which the small intestine was certainly involved, healed by spontaneous fæcal fistula.

Laparotomy also shows distinctly a larger number

of recoveries for penetrating wounds in the right colic region and the upper region, but the cases are numerous where penetration took place in the umbilical zone or was situated in the most central region of the iliac fossæ with tendency of the projectile towards the mass of the small intestine.

Lastly, if we recall the great relative frequency of bullet-wounds among the recoveries due to abstention, we shall arrive at the following practical conclusion :

In war, as in peace, operative results confirm our view that there is emphatically a preferable treatment for penetrating abdominal wounds, and that treatment is LAPAROTOMY !

CHAPTER VI

CONDITIONS AND SURROUNDINGS NECESSARY FOR LAPAROTOMY

LET us picture the surgeon and his assistant, the equipment, the distance from the front, and the difficulties.

I. THE SURGICAL STAFF

This must be trained and homogeneous. A surgeon cannot be improvised; still less can one successfully plunge into laparotomy for a deep-seated wound without a previous mastery of abdominal surgery; no operation of an urgent surgical nature is more full of unexpected accidents, or calls for more prompt decisions and more rapid execution; it demands at the same time both experience and manual skill. In a minor degree, the same requirements are necessary in the surgeon's assistant. Quénu asserted with perfect justice: "The idea that one can train an assistant in a few months seems to me a gross heresy."

The anæsthetist must be equally experienced, for it is necessary to produce steady anæsthesia (a condition important in rapid surgery) with the minimum amount of anæsthetic.

The nurses ought to be perfectly familiar with what is required of them. It is easy to obtain intelligent and active military nurses. The surgeon must train them efficiently if he wishes to have trustworthy and reliable assistance.

II. Equipment

We will consider this, successively, under the three conditions in which laparotomy has to be performed: in the ordinary ambulance; in the automobile surgical ambulance (the *autochir*, to speak briefly and in the language of the hour); and in the advanced surgical station near the front line. And as we have to do with a matter which may be left to the initiative of the army surgeon, we will describe in detail one type of each class.

A. *The ordinary ambulance.*—It is obvious that we have not to consider the case of a "travelling ambulance" (*i.e.* an unspecialised regimental or divisional ambulance). The very example which Picqué quotes is the best proof of this: In September 1914, in spite of a stream of 3,735 wounded in eleven days, he was able to operate in all cases of those wounded in the abdomen, where they seemed to him to be suitable for operation, and 9 laparotomies were thus undertaken among 135 operations. We have nothing but praise for those who showed such activity, but it is evident that the conditions under which the operations were performed would have been infinitely better if the 3,725 wounded had been sorted out at the same time, if Picqué's ambulance had performed three or for times the number of operations, and had occupied itself with operations only—that is to say, if it had been specialised only for surgery.

Laparotomy, with the necessary safeguards, will never be feasible except in a special surgical ambulance. We need also suitable special equipment and situation. An enviable example is described by Picqué. "A site, as large as possible, having been chosen for an ambulance station, we must consider also the general appearance of the premises, and in accordance with these make a logical arrangement of the cases, separating head wounds, and wounds of the chest and abdomen,

from those of the limbs only ; then make room for the formation of an operating-theatre and its offices. It is then possible to arrange immediately, in any place, a sufficiently aseptic room by using the surgical van for the first few hours as a preliminary sterilising station. The addition to our ambulances of the older type of two automobile cars for sterilisation and radiography, provides us to-day with an excellent portable, aseptic operating-theatre, and with the immediate help of X-rays."

This description, together with that where Picqué gives the details of the transformation which he had been able to effect in one of his ambulance wagons,* excites admiration and envy. Everything is evidently perfect. . . .

But, writing for the ordinary surgeons of the army zone, we think it best to warn them to consider as very exceptional circumstances which would enable them also to obtain similar transformations and additions. Generally speaking, the equipment of their ambulance will be gradually added to ; an autoclave, a hot air steriliser, and instruments for laparotomy ; and at every change of place one must carefully set up new premises in lieu of a portable equipment for immediate use. What a long way off appears the seductive mirage of "an instantaneous equipment," and how rarely will one find oneself provided with "a site as large as possible" ! It would need hours and hours, running into days, before one dare to open the abdomen !

What we must insist on in every case is, that when called on to perform operations for abdominal wounds, *an operating-room should be set apart specially for such cases.* In my opinion this is a condition of supreme importance. It is not so much in order to comply with the demand for strict asepsis (when in times of peace one has to perform any kind of urgent operation in any kind of country place, we know that

* See *Bull. et Mém. Soc. de Chir.*, 1915, p. 1792.

it is always possible to arrange for surgical cleanliness), as to have available immediately an "instrument ready for use" automatically without hesitation, preparation, or delay, and without unnecessary mental strain to the operator. The size of the premises matters little; in our last installation, we only set apart in our

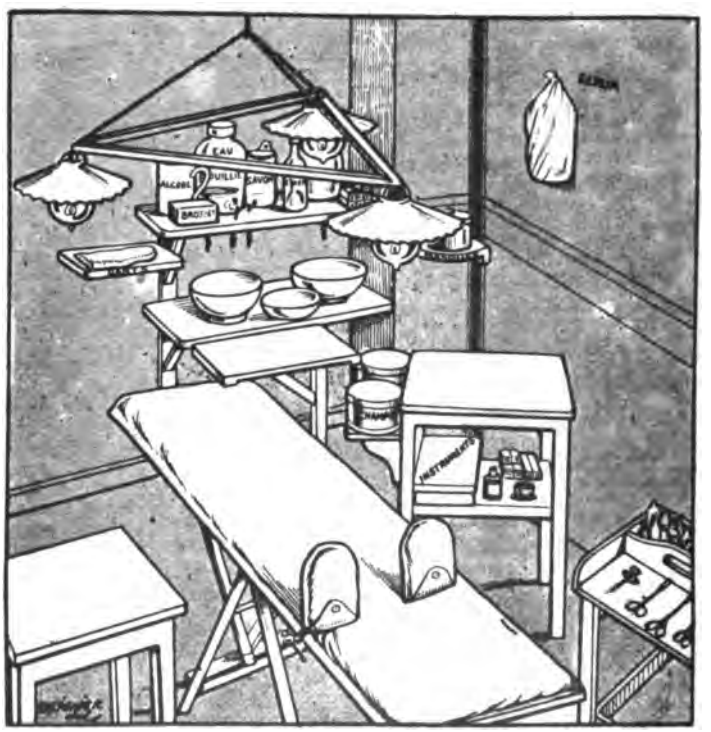


FIG. 29.—Compartment reserved for laparotomies in our principal operating-room by means of a wooden partition prolonged upwards by stretched sheets. (Hôpital de l'Ecole Margaine, Sainte-Menehould.)

ordinary operating-theatre a compartment, 3 metres long, by 2 broad, made by a wooden partition 2 metres high, carried up to the ceiling by means of stretched sheets (Figs. 29 and 30). But at any moment there were ready, for instant use, the operating-table, two tables for instruments, on which were already boxes

of sterilised bandages and instruments sterilised by hot air, just waiting to be taken out of their boxes, sterilised gloves, a basin with sterilised brushes, the anæsthetist's accessories, phials, and bottles of saline; in short, all that nurses as well as surgeons ought to be certain of finding ready so that the opera-

FIG. 30.—Laparotomy taking place.

tion can be prepared for and carried out as *automatically as possible*. For we are not talking here of being able to perform, in an exceptional manner, an operation to which one has leisure to give every conceivable care, but of the case when one must be able at any time, above all at periods of great surgical stress, to perform with the greatest rapidity and with the mini-

mum of nervous fatigue, a delicate operation which will have been preceded and will also be followed by an uncertain number of other operations.

It is the surgeon's duty to obtain and to set up such an installation.

B. *The automobile surgical ambulance.*—Here, on the other hand, everything one could wish for carrying

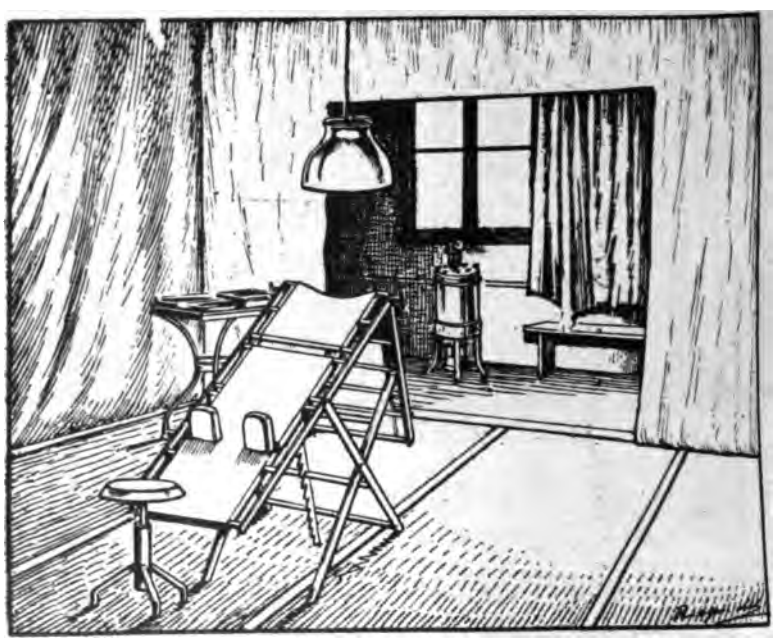


FIG. 31.—Arrangement of an operating-room in an advanced surgical post, near the front. Boigey [80].

out the most delicate surgical operations is found ready in advance. But the arrangements of the operating-theatre and its accessories are, however, variable, and will allow of special adaptation for a series of laparotomies. Roubillois'* model gives a very satisfactory arrangement of the different parts of the ambulance, because it provides for a strictly aseptic room reserved for abdominal operations.

* *Bull. Soc. Chir.*, 1915, pp. 1453, 1454.

C. *Advanced stations for surgical operations in the neighbourhood of the front line.*—These stations, being definitely intended for those wounded in the abdomen, for vascular wounds accompanied by profuse hæmorrhage, and for broken limbs, contain everything necessary for urgent abdominal operations.

We will suggest three examples which surgeons at

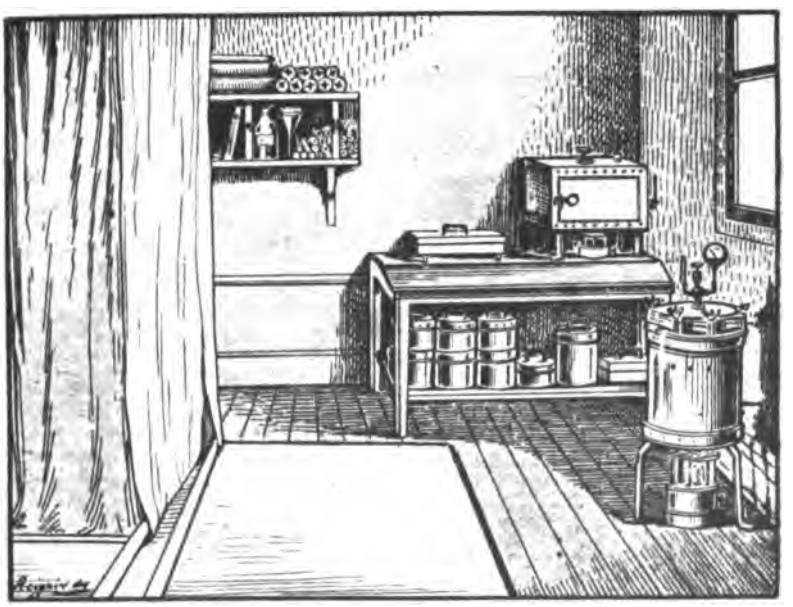


FIG. 32.—Transportable sterilisation apparatus in an advanced surgical post, near the front. Boigey [80],

the front could, as occasion offers, imitate or modify: those of Mignon [79], of Boigey [80], and of Tisserand.

The first and second form part of the same institution due to the generosity of Mme Fould.* It consists of a complete transportable equipment which can be set up within any four walls: an aseptic operating-theatre as well as a sterilisation

* It is in this station that Bouvier and Caudrelier, and afterwards Lucas-Championnière and Delay, obtained the results they have published.

annexe ; the walls, ceiling, and floor of an operating-room, an electric light plant, sterilising apparatus, operating equipment, and a radiographical outfit, which altogether weigh only 5,400 kilogrammes. The whole is transportable by an automobile lorry. Figs. 31 and 32 give some idea of the installation after it has been set up.

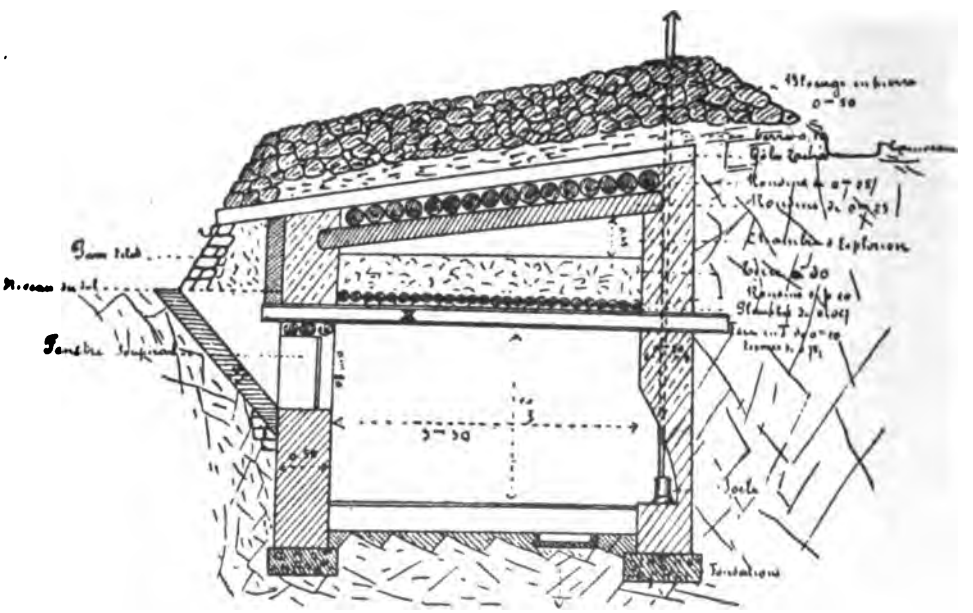


FIG. 33.—Mode of protection of a shelter for the performance of urgency operations in an advanced post near the front.

Then we have to find on the spot a house ; and a house which can be protected from artillery fire. The story of the unit which we have described above, which on two successive occasions had to leave the sites where it was at work, shows that these conditions cannot always be permanently assured.

It is this fact which gives special interest to Tisserand's description [17]. This shows us a subterranean shelter (of which we give a section, Fig. 33) where the surgeon has been ingenious enough, in the absence

of any plant, to supply its place and then prepare an aseptic operating-theatre.

Is a radioscopic installation necessary?—It is often useful, never indispensable. We shall see, indeed, in the following chapters, that the information furnished by X-rays may be influential both in determining the operation (by helping the diagnosis as to the depth of the wound and the lesions), and in the actual conduct of the operation by enabling the surgeon to determine beforehand the position of the projectile which it is almost always advantageous to remove.

But we shall see also that the data furnished by the radioscope are rarely sufficient in themselves to furnish indications either for or against an operation, which have not already been in a great measure, established clinically. We must remember also that the aim of the operation is the reparation of the lesion, not the removal of the projectile. A radioscopic equipment is found in the *autochirs*, and in the advanced transportable stations we have already mentioned.

Picqué was able to attach a radioscopical car to his ambulance; but even in the fixed surgical units, which we have seen around us, a radioscopical car comes only on a fixed day and for an hour or two, and it is therefore only a coincidence if the radiographer is there to give the surgeon pre-operative indications in the most interesting cases, *i.e.* in those of the abdomen and head.

We repeat what we have already written. Is a radioscopic installation useful? Yes, but not indispensable.

III. Distance from the Front—Delay in Operating

The influence of the distance from the front on the development of abdominal wounds in general, and especially on the results obtained by laparotomy, is proved by two concordant pieces of evidence.

The farther a man with an abdominal wound is carried before he can be allowed to remain quiet in one spot (which, whether he is to be operated on or not, is an essential condition of cure) *the worse are the consequences.* Here is a proof of this: when, for strategical reasons, for example, one is obliged to evacuate all the wounded to a distance, one sees, as one goes from an advanced unit to one farther behind the lines, that the number of abdominal cases rapidly decreases. Those with abdominal wounds do not easily stand being moved; among them excessive evacuation produces a very high mortality.

The later an operation is made for an abdominal wound, the more disappointing are the results.—All surgeons are unanimous with regard to this impression, and it it is confirmed by statistics. Given equality of lesions, recoveries are more frequent the sooner the operation takes place. We must note the "equality of the lesions," and not limit ourselves to contrasting the number of deaths in the very early stages with those which follow at a later period. In the early stages, in fact, the coefficient of mortality is very high; this is due to the fact that the surgeon, especially if he is in the habit of operating systematically whatever the degree of gravity of a case, is led to operate on cases which are almost hopeless; death or a rapid aggravation of their condition would have swept them away naturally if they had only reached the surgeon's hands at a later period. But after the fifth or the sixth hour the figures again assume their significance; the results are less and less favourable the more the operation is delayed.

For this reason one may say, therefore, that considered with regard to other injuries, abdominal wounds deserve special consideration. For the majority of cases of ordinary wounds the tendency is to follow the plan of establishing at 15, 20, or 25 kilometres from the fighting lines large "surgical centres" and

to aim at bringing the wounded to these in automobiles as soon as possible. These centres out of reach of the guns, free as a rule from the local or momentary variations of the front, compensate largely, by means of complete and regular attention, and security of rest, for the relative disadvantage of an additional transport of some kilometres. This plan is intermediate between evacuating every one as far as possible to the hospitals at the base—a practice which seemed logical when the conviction was held that most wounds remained aseptic when covered by a single protective dressing—and the practice of surgery in the ambulances at the front which seemed for a time an ideal method on account of the great frequency of shell or trench-mortar wounds, and the constantly septic condition of such wounds. The most recent bacteriological results, however, have shown that septicæmia only sets in after the sixth hour; surgical centres from 15 to 25 kilometres behind the front line sometimes allow operations to be performed within this period; it is, therefore, a case for rapid evacuation. For penetrating abdominal wounds, such a distance from the front is unacceptable. This is on account of two consequences which it involves: first, the time which must pass between the wounding and the operation, and secondly transport. The second is undoubtedly the more important! With a given intensity of lesions and the risk of hæmorrhage or infection, it would be better to operate at the tenth hour on a wounded man who had not been moved, rather than at the second on a man who had been disturbed, pulled about in various ways to be got out of the trenches, then shaken, in spite of every care, by the jolting of an automobile, and whose disturbed intestines cause a flow of blood and septic fluids into the abdominal cavity from themselves or the surrounding tissues.

Of *two solutions* which present themselves—one,

to carry the wounded to the surgeon by rapid transport, the other, to bring the surgeon to the wounded, the first has been shown to be impracticable.

Doubtless under all circumstances we ought to try to make transport as quick as possible (we shall see how later on), but one cannot with impunity rush a man wounded in the abdomen over long distances, and it is sufficient to have seen men arriving ten or twelve kilometres behind the lines, wounded in their limbs, and suffering from the shock of transport, to be able to imagine how much more injurious still would be such transport for a man with an abdominal wound. "Two or three kilometres more or less in an 'auto,' why, that's nothing at all!" people have been in the habit of saying. That's true enough for almost all the wounded, even for chest wounds; but it is altogether false as regards deep-seated abdominal wounds. *A fortiori*, we cannot accept the statement of Chavannaz that, if necessary, one may transport a man with an abdominal wound 50 kilometres in order to find a perfectly equipped hospital unit. The only solution evidently is to bring the surgeon to the wounded. But there are various degrees of necessity.

Although Fiolle * was able to conduct successfully, under a shelter actually within a trench, a laparotomy which did him the greatest credit, one cannot deduce from that a general method of procedure; and all the more so because a surgeon without the necessary apparatus is rendered powerless.

It was this leading idea which led to the creation of the *autochir*. To Marcille, to whom belongs the credit for the original idea, and to the other surgeons whom civil practice in peace-time had taught what is the necessary minimum for the performance of emergency surgery, and especially of abdominal operations, the question was one of obtaining the conditions necessary for a successful operation. Without going

* Quénu, *Bull. Soc. Chir.*, 1915, p. 1886.

outside our subject we cannot here trace the history of the autochirs, nor show how it was possible to find fault both with their composition and also with their actual usefulness as representing only "the realisation of half of a very good notion."

Since they were to a large extent created for the purpose of enabling laparotomies to be made in the immediate neighbourhood of the fighting line, let us limit ourselves to the consideration of how close it is possible for them to approach. They cannot get nearer than ten or twelve kilometres; in the first place, because they are too heavy and form too complex and too important a unit (18 cars, including 4 large wagons); and also because it is not practically possible for them to give the surgical output one has the right to demand from them unless they are attached to a small hospital building already constructed, for even if portable the necessary huts have first to be erected. One comes to the conclusion, in fact, that, in spite of the mobility of their actual vehicles, the autochirs themselves are not very mobile.*

From the point of view, therefore, of distance from the front, the *autochirs* are exactly in the same category as divisional ambulances or army ambulances directly intended for surgery. (Later on we will consider their comparative output.)

It remains, therefore, to make a comparison between, on the one hand, advanced surgical stations which bring the surgeon as near as possible to the wounded, and, on the other hand, stationary ambulances from six to twelve kilometres from the front, whether they be automobile or not.

At the advanced station the operation is performed under the best conditions for success. Bouvier and Caudrelier operated on the wounded during the very

* Setting aside typical cases, which we have seen and noted personally, we will content ourselves with a reference to P. Delbet (*Soc. Chir.*, 1916, p. 1110).

first hours; but the full advantage of this is only gained if the station is absolutely safe from bombardment and if both the operating surgeon and the patient can

FIG. 34.—Trench stretcher (Eybert).

be ensured, not perhaps absolute, but comparative quiet during the days which follow an operation.

If these conditions are not secured, if severe fighting alters the front line, if the uncertainty of the next hour or even of the next day adds to the anxieties of the operator and exposes the wounded to a sudden evacua-

tion, in short if the station becomes "unhealthy both for the wounded and their attendants," it is indisputably better to take the wounded at once to a surgical unit farther off which will assure him a longer and more restful stay in hospital after the operation.

Wherever he is to be operated on, near or far, there is one stage to be got over in the case of an abdominal wound to which too much attention cannot be paid, for it is of the utmost gravity—that is the evacuation from the trench, and the transport to the point where he will be placed in an automobile. This is often a veritable Calvary, lasting perhaps two hours or more, interrupted by all sorts of shocks and difficulties! This is the most injurious time for the wounded.

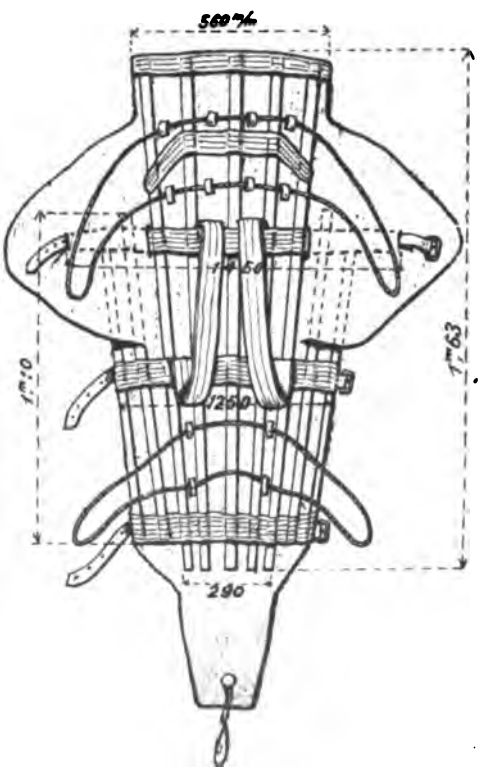


FIG. 35.—Immobilising stretcher (Martignon).

The surgeon may use his influence to enable him to use the evacuation trench for the wounded; such trenches or galleries are to be found almost everywhere; but before using them it is wise always to ascertain their size. Gatelier declares that in his sector the commandant had caused special large galleries to be constructed for this purpose, and that

these saved an hour in the transport. We have also to consider the different methods and apparatus required in bringing the wounded to the shelters, the gaps in the trenches, the corners, and to arrange for places where relays of wounded may pass each other.

Many doctors have devoted themselves to the consideration of the best kind of stretcher for trench-work. Gatelier has those wounded in the abdomen carried on a piece of tent-cloth with their knees raised; others use a kind of carrying-chair with the patient in a sitting posture; this has great advantages. Eybert's stretcher is of this type (Fig. 34). Matignon's stretcher keeps the trunk and the lower limbs as steady as possible (Fig. 35); the wounded man is "sausaged," that is to say he is packed up like a mummy and carried as if he himself were a stretcher or a hammock, or like a sack of corn carried on the back.

In spite of all these efforts, we must not forget that during an actual attack, in spite of the zeal and promptitude of the stretcher-bearers, the evacuation may be very slow, and a distance which ordinarily would be covered in two and a half hours will take in actual war-time six hours, or even more!

Transport from the first-aid station to the ambulance is done by automobile. It is very rapid as a rule, and we cannot recommend greater speed in bringing the wounded to the surgeon; on the contrary, more often than not, the surgeon advises the chauffeur to go more slowly so as to avoid too sudden shocks.*

Is this mode of transport "the perfection of smoothness," as Picqué writes? No. One has only to try such a journey for oneself, or, more simply still, to examine the wounded on their arrival, to discover that

* M. le médecin inspecteur Follenfant is of opinion that the only way to obtain a reduced speed from the chauffeurs, and to oblige them not to exceed it, is to modify the gear-wheels and thus to diminish the ratio. The experiments already made in Morocco have been quite satisfactory.

they are suffering from shock. But it must be owned that at the moment nothing better can be done.

What one should try to do, however, is to arrange that those suffering from abdominal wounds are not evacuated from the trenches in the same way as the other wounded. These are taken from the field-station to the sorting ambulance; they are fetched twice during the day, and carried to the evacuation hospital or the hospital ambulance. It is *absolutely necessary* that the abdominal cases should be placed immediately, direct from the trenches, in the automobile and taken at once to the surgeon without waiting for the ambulance to be fully loaded. Precious hours are thus gained.

To sum up: The problem presented by distance from the front can be solved in the following manner. In times of steady fighting and in periods of calm laparotomies should be undertaken in permanent advance stations; in other than these rather exceptional conditions laparotomies should be performed in stationary ambulances ten or twelve kilometres from the front, but with as rapid transport as can be obtained by means of special evacuation galleries and by direct transport to the surgical centre without any intermediate stopping-places.

IV. Over-crowding

The sudden influx of large numbers of cases inseparable from irregular fighting presents a distracting problem to the surgeon, one which Sencert, Stern, and almost all those who have experienced it describe feelingly. It is no use treating it with sentimental arguments: it is a matter of cold calculation and pitiless arithmetic.

One abdomen, one laparotomy, means a whole hour devoted to an altogether uncertain result; it means at most half a chance of saving one man; an hour given to other severe wounds (heads, limbs, etc.) means that

you will save three at least.* Therefore, as the stream of wounded increases, one has to make a choice amongst the abdominal cases. And then it is that, quite rightly, one sets aside those which may possibly get cured to a certain extent without an operation; *i.e.* cases of bullet-wounds or wounds which on clinical examination do not appear to be accompanied by clearly marked adverse symptoms. One operates on the others. But at last an hour comes when one hesitates no longer, when one abandons to their uncertain fate all those with abdominal wounds, hoping, in order to calm the revolt against one's own helplessness, that the very refusal to operate may be rewarded by some cures.

Are these over-crowding difficulties inevitable? One might have thought that, thanks to the selection which is exercised in sending the wounded to them, and thanks to the perfection of their equipment, surgeons of the automobile ambulances might be able to avoid them; but, according to Chevassu, they themselves own their helplessness, and, not content to resign themselves to it, use it as an argument against the partisans of operation. It is well to remember what Quénu has demonstrated. Even on the day when the stream of wounded was greatest, all those taken to Chevassu could have had the advantage of the normal treatment for abdominal wounds—that is to say, of laparatomy when an operation seemed indicated—if two or three additional plants had been there; if, for instance, one or two autochirs, not in use elsewhere (for that is the important fact) had been sent at this time to the point where they were undoubtedly needed.

For these reasons the Chirurgical Society is quite justified in the desire that it has recently expressed.

* "But," some will say, "a man with an abdominal wound once cured is completely restored, whilst the others are often left mutilated!" Granted, but from a social point of view (family, earning capacity, procreation) six mutilated men are worth more than one even with an abdomen completely healed.

After having heard many facts as to the misuse of autochirs, it asks that "in order to secure for those wounded in the abdomen and also for all others seriously wounded, treatment in which the rapidity of the operation has a considerable influence on its success, the automobile ambulances should be concentrated at the point where the stream of wounded is greatest according to the need for them and for as long as is necessary" (May 10th, 1916).

To discuss here the question of the use of autochirs would be to go outside our subject. It is, however, useful to consider one point.

An autochir, a medium for urgency operations, cannot produce its maximum output—that is, its normal—unless the evacuation of cases operated on, as soon as they are transportable, is kept also at a maximum. It follows, therefore, that every autochir (and even every surgical ambulance specially set aside for emergency operations during war) ought to be *attached to a railway line.* To place one of these units five or six kilometres from a railroad is to transform it at once into a hospital "for treatment," and this is not what it is intended for. Its *rôle* is to make it possible to evacuate by operations those wounded who cannot be evacuated before operation, and only to keep for a minimum time those whose wounds urgently demand treatment in a hospital on the spot. A surgeon, therefore, will permit those wounded in the thorax, head, or abdomen to travel to a surgical station, or even to the base, and will even consent to a twelve hours' journey, provided this be made *by rail,* whereas he will firmly refuse to sanction such a journey if it has been preceded by even three or four kilometres in an automobile!

So here we have a source of rapid overcrowding. To secure a prompt, regular, and safe evacuation is to more than double the output of every advanced surgical station; especially does it give the surgeon opportunities for operating on and attending to abdominal

wounds. Thus the necessity for proximity to a railway is obvious.

Can one imagine a factory without a rail to take away the goods? *A surgical station is a "factory."* There are brought to it the "raw products," the wounded not fit for evacuation; the station transforms them into "manufactured goods," the wounded ready for evacuation.

This we must admit as a fundamental idea, and always bear it in mind, for from it arise consequences rich in results, advantages of concentration which allow of more complete general services with less fatigue, necessary specialisation, and a rigorous use of departments according to their differentiation, a general tendency for work to go on automatically, and the organisation of everything connected with the surgeon, the chief "instrument" on whom depends the output, etc.

Another idea strikes us as a complement to the first. Surgery is not only a science, an art, but also a *sport*; the expenditure of physical force ought to be reduced to a minimum by making the movement *automatic*, and also by saving the operator himself from outside worries; the organisation, the actual working, the collaboration of each assistant, ought to come into the game automatically at moments of high pressure. Finally, the surgeon at the front ought always to be thinking more about the wounded who may be brought to him rather than of those on whom he has already operated and attended to; to do his duty to the wounded who may come from the front lines to-morrow, he must know how to get rid of the wounded of yesterday.

And now for those matters which concern the surgeon much more directly. In any kind of surgical unit whatever, if one wants to make a series of laparotomies, *one must have a unit specially intended for abdominal operations, and for those only;* a complete staff, so that the surgeon, before deciding to operate, will never have to weigh their relative usefulness for

abdominal or other wounds, but who are assigned solely to a specific task (but not therefore necessarily less interesting or less common).

In a surgical automobile ambulance, internal organisation, and division of labour are of the utmost importance; of the three or four units of which it is composed one can be set aside for laparotomies.

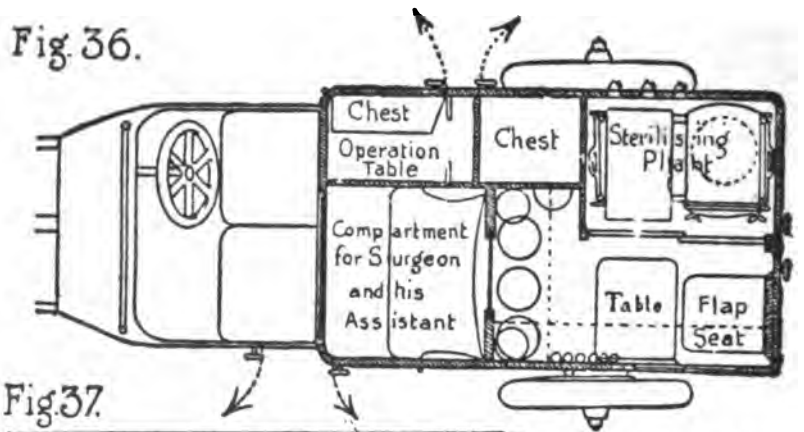
In a surgical centre where there are many ambulances working at the same time an effort should be made to concentrate all abdominal wounds in one department.*

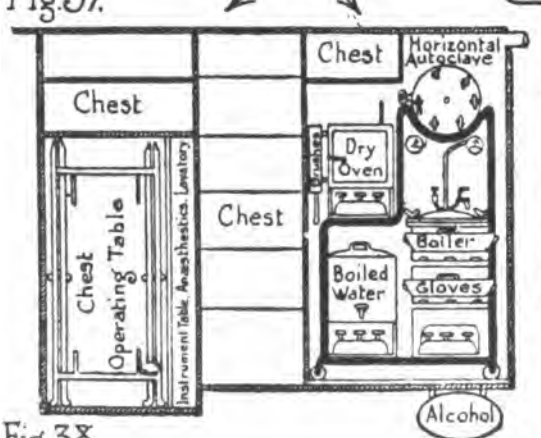
In all ambulances the question is a difficult one, for there are at most only one or two surgeons, and each has enough to do when from 100 to 150 inevacuable wounded arrive in the twenty-four hours †; each doctor does his utmost to the limit of his endurance, and that may last for two, three, occasionally even four days. Then follows a period of calm, and then it is that one makes the returns of the abdominal cases which remain or have vanished!

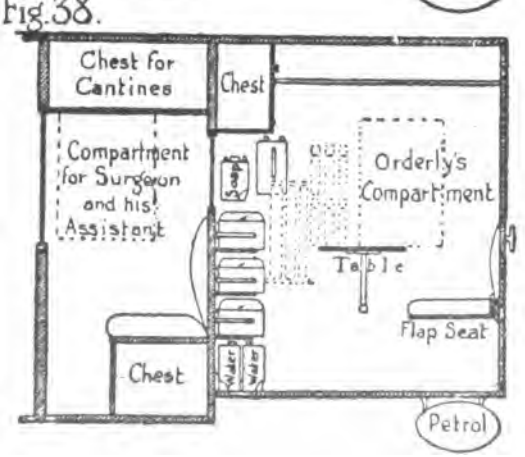
At this moment of stress, then, there should be available a *supplementary unit*—perhaps two, but one at least which should be strictly kept for abdominal wounds. And when I say a unit, I mean a complete unit: surgeon, assistant, anæsthetist, orderly, and everything that is necessary: instruments, operating plant, sterilisation plant, and all kinds of dressings. This unit should not have to borrow anything from the ambulance which it comes to help and relieve, nothing but two stretcher-bearers (working almost continuously) and some kind of premises. And if no kind of

* In June and July 1915, when I was the only surgeon in our ambulance, I was able, with the help of my *confrères*, to examine 943 wounded in a month, and to operate personally on 627, an average of 20 a day, with on three occasions a maximum of 62 and 60 a day. We were only dealing with grave cases of men not able to be evacuated, and the operations were under general anæsthesia.

† Some recent changes have proved that the specialisation of services, the direct and rapid transport of the wounded, and improvements in outfit can be obtained even without being asked for.







premises are available (four walls and a roof), one must consider the possibility of the reinforcing unit bringing with it a portable operating-theatre. "But you are describing, then, an automobile surgical ambulance? That already exists!" No, certainly not! What is needed in an emergency is an

FIG. 36.—Chassis 20 h.p., 8 cylinders seen from above.

FIG. 37.—Right side view.

FIG. 38.—Left side view.

FIGS. 36, 37, and 38.—Surgical automobile for operations close to the front. (Abadie.)

arrangement for immediate reinforcement, simple, pliant, and mobile. (It is not possible to confuse the two things.) Two automobiles (not wagons) would be enough; perhaps even one only.

In a survey made in December 1914,* I described, with all the details of its arrangement, an automobile which should allow a surgeon to travel quickly to any given point with what I call "his ordinary operating outfit" (Figs. 36, 37, 38). In my opinion this survey lost nothing on account of the practical side which I endeavoured to give it. No operating-theatre was provided for, however; and one might be useful. There are two ways of solving the difficulty: either by adding to the weight of this surgical automobile by panels necessary for the construction of an operating-theatre (that would necessitate turning it into a heavy and slow wagon), or, by adding, if necessary, to the automobile already described another light car which would carry the constituent parts of an operating-theatre, and finally one could add a radiological plant, as in the unit given by Mme Fould and described by Boigey.

These different units, the surgeons and autos, would in the ordinary way be at the disposal of the Director-General of Army Medical Service who could thus reinforce any particular over-worked ambulance by sending it a supplementary unit.

It has been objected that such a unit would not always be well received, and that the wounded whom it could treat for only two or three days, and would then have to turn over to the care of the ordinary ambulance, would receive less interest and attention. . . .

To think this is, I believe, to fail to realise the state of mind of an overworked surgeon who feels the stream of wounded behind him growing greater and greater, who will no longer venture outside the operating-theatre, so painful to him is the sight of the anxious

* *Presse médicale*, February 1915; supplement, p. 38.

eyes turned towards him, and who, transformed into an operating machine for hours and hours, has but one desire—to make only those movements which are absolutely necessary, so as to gain time, and to economise his own strength that he may last out. How would it be possible not to welcome joyfully those who come to help you to care for the poor waiting men *before it is too late?* And how, later on, would it be possible not to look after, as if they were one's own, the cases of laparotomy which have had the exceptional luck to be saved by an opportune operation?

It is objected also that the laparotomy cases will crowd up the hospital wards of the ambulance. Not more so, once operated on, than by waiting there to be cured without operation; . . . at least, not unless it is suggested that in the cases of no operation a greater number of beds will soon be emptied of their occupants!

"But," it is asked further, "what will be the output of a unit entirely occupied with laparotomies?" One can allow, I think, that without any considerable strain (at any rate, for eight or nine days), a unit in working order can put in twelve hours a day of work at high pressure; the number of laparotomies which a surgeon can do in a day is between eight and twelve. If, in conformity with the statistics of results furnished by laparotomy, a unit has the satisfaction at the end of the day of having saved four or five wounded who would otherwise have been condemned to death, its labour will not have been in vain.

The desire for mobile units is not new.

We have seen them suggested in the course of previous wars (Chap. II.). And the necessity for specialisation * is also proved by many surgeons of our Army—men who are not mere plagiarists, but

* Evidently it is a long way removed from the usual tendency of having men, methods, units, all interchangeable; it is much less simple than having *passe-partout* (master-key, to fit any lock) Field Hospitals, or *passe-partout* doctors, who will be limited to the *passe-partout* operation—Murphy's!

who, having worked at the front and known its exigencies, are quite agreed on this point; amongst them are Leriche, Delay, Simonin, Grégoire, and quite recently Monprofit.*

Agreed! That is all very well in trench warfare, in the "abnormal" war which we are passing through. What will happen to all these improvements in a war of movement?

For here we have the double notion generally admitted of which R. Picqué † has made himself the exponent: "There are two kinds of military surgery: the *false*, that of preparation or stationary conditions which permit the application of all the surgical principles of peace-time; and the *true*, that of active conditions during which, in spite of all that can be done, those wounded in the abdomen will probably suffer."

It may be objected that this conception of a *true* war (that of movement) and of a *false* war (that of the trenches) ought to be relegated to those other attitudes of mind which the present war has shown to be out of date.

"We are not able to believe," wrote Humbert in the *Journal*, "that this long immobility of armies face to face in entrenchments blocking all the available space from the sea to the mountains is merely an accident, a more or less abnormal phenomenon, destined nevertheless to come to an end some day, to give place to the real war, a war of movement, the doctrine taught by the professors of Napoleonic tactics. No, this stagnation, these interminable bombardments, this mechanical pounding at human lives, this is *war*, the war of to-day, the war in which we are engaged, the war which we have to carry on!"

The differences of opinion about this matter vary little. Stationary warfare has shown itself to be long

* *Soc. de Chir*, May 10th, 1916; *Bull.*, p. 1159.
† September 13th, 1915 (*Presse médicale*), Fifth Army.

enough and wasteful enough of men for us to realise that every kind of organisation which has been able to diminish the waste (even if attached to special tactical conditions) will be amply justified!

But will a war of movement really invalidate all the conclusions at which we have arrived? No, certainly not. It will oblige us still more to make the autochirs independent and mobile, and, thanks to their mobility, to concentrate them at the points where the influx of wounded is greatest and to make them work in connection with the railways. It will necessitate for the ordinary ambulance an equipment which will make quick surgical work possible. It will show the still greater need for mobile units to reinforce the others. The main thing will be to use wisely those resources which we actually have at present.

There will perhaps be room also for an arrangement, so far non-existent, although previous wars have shown its necessity: viz. the *surgical train.* During the Russo-Japanese War operating-theatres were improvised in railway carriages ordinarily used for passengers or goods, and at the moment when peace was concluded a train of this type was ready in every important railway-station.

Hautefort [82] describes an arrangement of this kind. How often has many a surgeon at the front ardently wished that he could operate actually in the train itself! Then the wounded, thus become evacuable, would pass directly from the operating-theatre (so easy to arrange in a railway carriage) to the train which would carry them away! More than three-quarters of those operated on are ready to go away at once; the others would go to the hospital huts in the neighbourhood. How much greater rapidity, both in attention and in evacuation! What simplification of transhipment! What delay and shaking spared to the wounded! What economy, in fact!

Once more the axiom would be verified that "the railroad is the beginning and the end of the military medical service during the battle" (Follenfant). So many simplifications which would, as a natural consequence, set free many units and premises for the rational treatment of abdominal wounds.

. . . . . .

Conclusions.—Study of the conditions necessitated by the application of laparotomy to penetrating abdominal wounds leads us to two kinds of conclusions; one concerns the general organisation, the other that of the conduct of the surgeon himself.

Is it not the part of those who are working and observing in the front zones to give by facts, impressions, and arguments suggestions for the consideration of the organisers themselves and for those who, from headquarters, preside over the general arrangements? To them we say:

1. Abdominal wounds are by no means negligible; on the contrary, both by reason of their frequency and by the statistics of possible recoveries, they claim that special means should be devised by which the good results can be still further increased.

2. The specific treatment is laparotomy. "Every argument opposed to this encourages inertia and error; it is pregnant with dangerous consequences and contrary to surgical truth."

3. Neither insufficient equipment nor delay in transport are obstacles to the practice of laparotomy if:

(*a*) The ambulances set apart for surgical use are regularly provided with the equipment necessary for rapid work wherever they may be;

(*b*) Autochirs are used as they ought to be;

(*c*) The specialisation of departments is organised;

(*d*) Mobile units for reinforcements are created.

And, above every other consideration relative to the wounded man himself, there are two reflections which ought to guide the personal conduct of the surgeon.

1. The surgeon at the front ought to try by every means in his power to obtain those general operative conditions which alone can make possible the best treatment for abdominal wounds, which both in war as in peace is laparotomy.

2. But if he has any doubt of himself, any distrust of his assistants, if he has not both the necessary instruments for the operation and the means of sterilisation ; if he can only operate with anxiety with regard to these matters, or if he is placed in such circumstances that a laparotomy will prevent him from attending in time to one or more other wounded whose cases are urgent, not only can the surgeon at the front be excused for not performing laparotomy, but indeed it is his duty not to operate, and it is not on him that the responsibility for this helplessness lies.

CHAPTER VII

DIAGNOSIS OF THE LESIONS—INDICATIONS FOR OPERATION

H——, wounded November 30th, 1915, had a "seton" (tunnel-wound) of the right flank by the splinter from a shell found in the dressing; on account of its very oblique direction, although its centre was nearly 5 cm. below the skin, this "seton" appeared to us latero-peritoneal, but not deep-seated. T. 37°; P. 92, very regular and strong. No operation. Healed without difficulty.

Here is an abdominal wound on which we did not operate. Why? Because clinical examination showed almost certainly that there was *no penetration.*

. . . . .

Br——, wounded May 1st, 1916, showed an abdominal wound from a shell-splinter which entered by the right axillary line opposite the tenth rib; exploration led obliquely towards the right anterior superior spine of the ilium. T. 38°; P. 112. No flatus; no stools. Muscular rigidity was localised in the right flank; no vomiting.

He was operated on; exploration of the track led to actual contact with the peritoneum and its lining of fascia; the projectile was lodged outside the peritoneum; counter-opening; drain; healing normal.

Here we made an incision. Why? *Because indications and symptoms were contradictory*; there was

doubt as to the penetration. (The operation was, however, stopped at the intact peritoneum.)

. . . . .

D——, September 26th, 1915, had a deep-seated wound below and to the left of the umbilicus made by some small projectile; the probe went easily through the wall. But there was no abdominal pain; the abdomen was supple; general condition excellent. T. 38°·4 (101·1° Fahr.); P. 96.

Besides, the wound was received thirty-six hours before. No operation. Cured. The radioscope showed a small shell-splinter projecting on the left of the vertebral column in the lumbar region and at the same depth as the vertebræ.

In this case the *penetration* was undoubted. Why was there *no operation*? Because there was *complete absence of abdominal symptoms* and because the absence of all reaction was the more significant when thirty-six hours had already elapsed.

. . . . .

L——, March 31st, 1916, had a penetrating wound at the side of the right flank; the right half of the abdomen was painful; general condition good; T. 38°·2 (100·75° Fahr.); P. 120. The operation showed that the wound went right into the abdominal cavity; There was found a perforation of the colon and besides that an appendix just on the point of suppurating! Recovery.

Why the operation? *Abdominal penetration was certain*, it is true; but the seat of the wound in the flank and side would have made it legitimate not to operate, and all the more so as the general condition was good and the abdominal symptoms localised. But there, again, there was *doubt* as to the nature of the visceral injury; it was better to operate.

. . . . .

M——, September 17th, 1915, had a deep-seated

wound from a shell-splinter 6 cm. above the right iliac spine. The abdomen was very painful; parietal rigidity very marked; no flatus, face drawn, pale, nose cold. T. 38° (100·4° Fahr.); P. 100. Immediate laparotomy disclosed two extensive and irregular longitudinal lacerations of the small intestine and a perforation of the cæcum. Recovery.

There was no hesitation possible here. There was *penetration*; there were undoubtedly *serious visceral injuries*; the *patient was in good condition.* Prompt laparotomy was successful.

. . . . .

H——, April 29th, 1915, had an extensive wound in the buttock near the anus; blood, fæces, and urine were flowing from it. The abdomen was painful. There was intense shock; the patient was bloodless, respiration faint, cold, pulse hardly detectible. One would have thought any operation impossible. But an injection of caffeine citrate, camphorated oil, warmth and rest restored the patient; two hours later one felt justified in making an incision. It was a complicated case; two perforations of the small intestine, a vast laceration of the bladder, and a laceration of the rectum were disclosed. After many ups and downs, the man recovered (see p. 517).

Here we have a case of *abdominal wound with serious lesions* inoperable on account of *shock*, where it is necessary to *delay the operation*; preceded by an active tonic treatment, an operation later on may meet with unexpected success.

. . . . .

L——, January 14th, 1916, received a deep-seated wound from a bullet which entered at the level of the ensiform process of the sternum and went out at the posterior axillary line between the eighth and ninth ribs. A little fluid of a bilious nature trickled from the gastric orifice. P. 76; T. 37°·5 (99·5° Fahr.).

No abdominal reaction ; slight thoracic hæmorrhage at the back. Recovery.

The indications *were against operation*, as this was an *abdomino-thoracic* wound without any alarming symptom either of hæmorrhage or of visceral lesion.

. . . . .

L——, on the contrary, April 22nd, 1916, showed a large " seton " extending from the thorax to the right side of the abdomen, with a wide opening in the pleura between the tenth and eleventh ribs, hernia of a loop of the colon with the omentum and wound of the liver and constant hæmorrhage. Incision made, the pleural cavity was closed by pressing up the diaphragm to the pleural wall, and the colon and omentum were cleaned. Nevertheless, death took place in a few hours. (See Fig. 27.)

Here the *situation was almost desperate*, but an operation might possibly give a *chance of recovery*; so the *incision was made.*

. . . . .

As a final example : P——, September 26th, 1915, had a large abdominal wound, to the left of the umbilicus, from which several loops of intestine were hanging, many of them perforated. The man was cold, hardly answered when spoken to, had no pulse. No treatment succeeded in overcoming the shock. Death.

What would be the use of attempting a laparotomy *predestined to failure ? One simply does not operate.*

. . . . .

The clinical examples we have chosen range from deliberate non-operation to non-operation due to impotence, and from laparotomy performed unhesitatingly to laparotomy undertaken " to satisfy one's conscience." We have purposely contrasted these, one with the other. These are, in fact, typical cases round which are grouped the different contingencies

with which the medical man may have to deal. But it is noticeable that in each case there are very distinct reasons for determining the action to be taken; this is a clear proof of the interest which attaches on the one hand to the clinical diagnosis of the lesions, and on the other to the discussion of the indications for or against operation.

. . . . .

Here is an abdominal case. The examination must be brief, the decisions clear.

The *interrogation* consists of eight questions:

1. Time when wound received (note on label).
2. Cause of wound (ditto).
3. Position.

Then follow:

4. Pain ?
5. Vomiting ?
6. Stools ?
7. Flatus ?
8. Micturition ?

That is all.

The *examination* includes:

1. Inspection of the *orifice* or orifices made by the projectile (the position, form, contents, discharge).

The investigation of:

2. The pain produced and the contraction due to rigidity, general or local.
3. Are hepatic resonance or dullness in the iliac fossæ and flanks present ?
4. Pale *face*, discoloured mucous membranes, *cold nose*, dark rings round eyes;
5. *Cold extremities.*
6. *Dyspnœa, restlessness.*
7. *Pulse* (frequency, compressibility).
8. Temperature; sometimes probing of the wound, catheterisation of the bladder, examination by the rectum, and pulmonary auscultation.

This done, the surgeon asks himself two essential questions, and two only :

First.—Is the wound a penetrating one ?

Second.—Are the viscera (especially the small intestine) injured ?

The *clinical diagnosis of the injuries* is limited to these points because these are sufficient to determine the course of the treatment.* One factor alone can now modify the decision as regards operation, based on the state of the wound ; that is, the general condition of the patient.

Is there shock ? Laparotomy may be perhaps deferred with advantage.

Is there hæmorrhage ? The operation should be made without delay, and any such wound as seemed likely to do well without operation calls for an immediate interference.

This concludes the *therapeutic indications*.

A. Clinical Diagnosis of the Lesions

The first question is :

1. **Does the Wound penetrate the Cavity of the Abdomen ?**

In certain cases there can be no doubt ; when through one of the orifices there is hernia of the omentum or of a loop of the intestine either full or empty.

Or perhaps there trickles from a gaping hole, large or small, a stream of blood sometimes mixed with intestinal fluid ; the exploring forceps or the finger goes freely into the abdominal cavity.

There, again, penetration is evident.

But, for the most part (and these are just the most

* One might ask oneself also : Is peritonitis present ? But this question has no practical value. Peritonitis certainly exists, but in a variable degree whenever one operates for an abdominal wound ; at this stage it is only an additional symptom which does not in any way affect the decision already taken, and where general peritonitis is verified, when it is sure enough to make an operation useless, this operation has already been made impossible on account of the delay between the reception of the wound and its examination.

interesting cases because they afford much greater scope for effective treatment), the injury is slight, already plugged by a clot of blood or by the superposition of the muscular and aponeurotic tissues. On what shall we rely to establish penetration ?

(*a*) *On the course of the projectile.*—A passage ending in *two orifices* would seem to give absolute certitude. Often it does, but sometimes it does not ; for instance, oblique passages near the groins, and the hypochondria, and where the orifices are close together. The further off the wounds are from one another the more likelihood there is of penetration ; but one must take into consideration the thickness of the wall (which one thinks of sometimes as much thinner than it really is ; Fig. 39 gives the proportions) ; one must also take into account obliquity in the vertical direction which lends itself to long tangential tracks (Fig. 40). Certain positions involving torsion of the thorax, and muscular protuberances, explain paradoxical occurrences. After the parts affected have been straightened out a course of the projectile, however rectilinear, would show an improbable path.

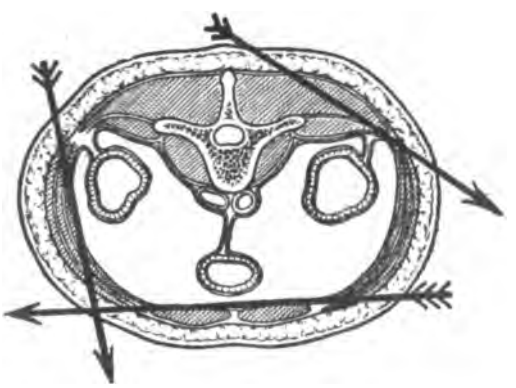


FIG. 39.—Horizontal section of the abdomen showing the respective dimensions of the walls and of the peritoneal cavity. One sees that the tangential passages may correspond (as regards the projectiles) to orifices of entrance and of exit at great distances from each other.

In fact, even with the modern projectiles, if they are at the end of their flight, the passage might be bent inwards by cleavage of layers of muscles ; these

passages, following the contours of the thorax or the abdomen, were more frequent with the old-fashioned projectiles.

Although very exceptional, it is not impossible for the two orifices to be situated nearly at the ends of an antero-posterior diameter and for the wound to be tangential. Quénu, in a case where the entrance was found near the anterior median line and the exit at a distance of a breadth of four fingers from the posterior median line, cut into it along its whole extent and ascertained that the whole of the walls, with the exception of the peritoneum, were involved. In the transverse direction the same fact may be observed. Rouvillois was thus led to make an exploratory laparotomy, this being the only means of verifying that a bullet going in at the right flank and coming out at the left, at a symmetrical point, had remained intrapa-

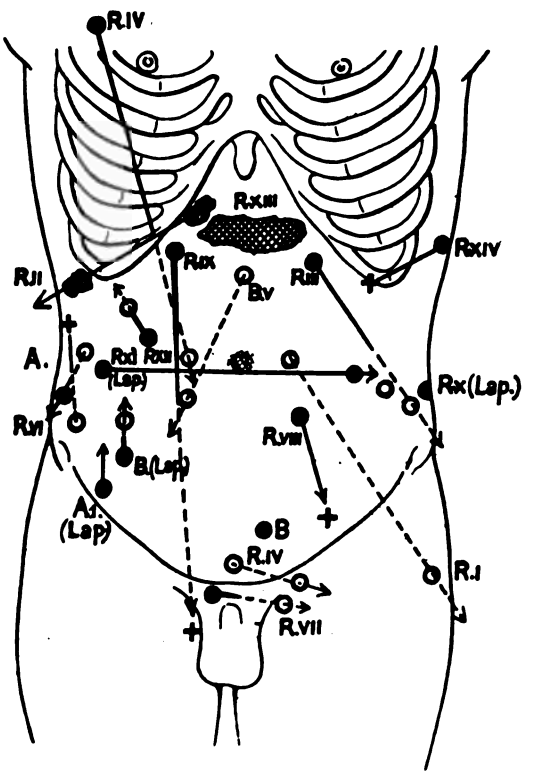


FIG. 40.—*A*—Abadie. *B*—Bouvier and Caudrelier. *R*—Rouvillois. Parietal wounds, not penetrating, operation performed. Notice the very great distance which often separates the two orifices without, however, the peritoneal cavity being involved.

rietal during the whole of its course. (See also Quénu [45].)

Severe injuries may lay bare the peritoneum without perforating it, and allow the underlying viscera to show through; if forced out by coughing, they form a large, tight hernia; we have several times seen wounds of this type. On the other hand, it may be necessary, in order to understand it, to separate the

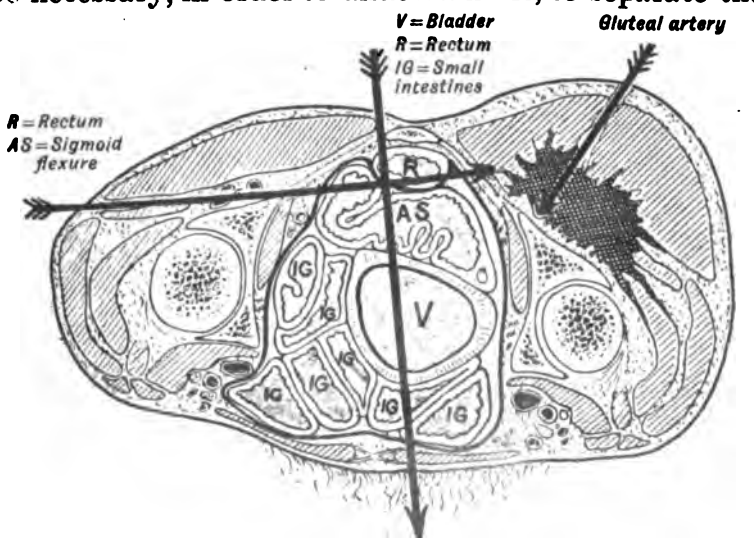
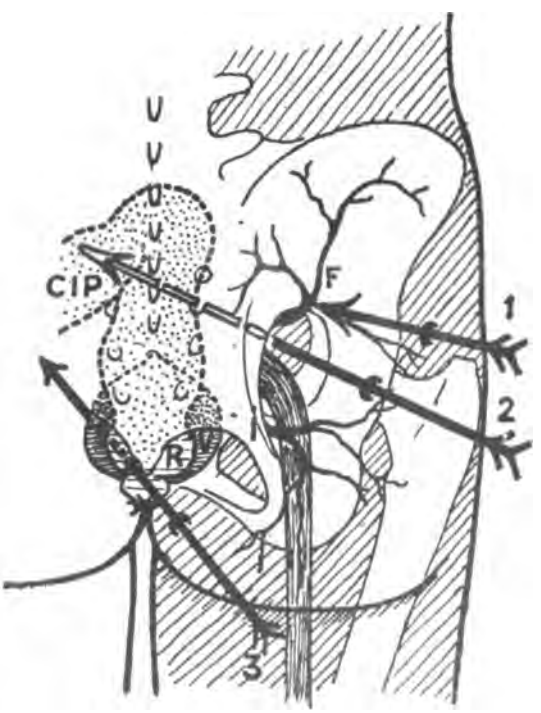


FIG. 41.—Horizontal section of the pelvis showing the usual passage of deep-seated wounds in the buttocks. Some of them cause profound hæmatomata, others perforate the pelvic viscera.

contused lips of the wound which by their approximation conceal the depth of the gap.

When there is *only one orifice*, and not two, the diagnosis becomes more difficult. Where is the projectile? We do not know its depth nor even the direction of its course. Probing will only occasionally give information; the too sharp point of the director, or Kocher's forceps, even the blunt point of a clamp, straight or curved, otherwise preferable, can only with difficulty pierce through the layers of the abdominal wall. One comes to an end or allows oneself to be

deceived by a false passage. And more often than not the position of the projectile remains unknown. One will be considered intra-abdominal though it really remained outside the peritoneum. (These are the cases which serve so largely to swell the statistics of the "abstentionists"!) And another will be considered purely parietal though it has really pierced the peritoneum. But if it is only slightly misleading to suppose a wound deep-seated when it is not, even if this leads one to an exploratory laparotomy, it is more serious not to recognise a deep wound, the tardy discovery of which will be too late to allow of a successful treatment.



CIP=Post-sup. iliac spine. *R*=Rectum.

FIG. 42.—*Typical deep-seated wounds of the buttocks.*—(1) Path of projectile injuring the gluteal artery or one of its branches; hæmatoma, infection. (2) Path of projectiles entering by the sciatic notch, injuries of the higher part of the rectum and of the sigmoid flexure or of the small intestine. (3) Passage of projectile which may remain extra-peritoneal but injure the rectum, the bladder, and perhaps the bony walls of the pelvis.

Since we are talking of wounds with only one aperture, we cannot insist too often on the frequency of abdominal penetration in *wounds of the buttock*.* This

* This fact should be noted in connection with the invariable

penetration is often unrecognised; then peritonitis discloses the seriousness of a little harmless-looking opening; it is too late, and the patient dies, for I have scarcely ever seen a buttock wound with abdominal penetration cured by "abstention." One must, therefore, be particularly on one's guard against it.

We must be on the look-out for it, too, in the case of long tracks across the buttocks! In "two cases," says Rouvillois, "the projectile had gone right through the bases of the two buttocks above and behind the great trochanter. It was only the autopsy which showed us, in the one case, a perforation of the rectum on a level with Douglas's pouch, with ecchymosis in the sigmoid flexure, and in the other a lesion of the rectum clearly intraperitoneal."

(*b*) Is the **abdominal syndrome** sufficient and sufficiently constant to complete or supply the place of knowledge of the course of the projectile?

Spontaneous abdominal pains, tenderness on pressure, defensive contracture of the muscles of the abdomen, stoppage of fæces and vomiting, rapid pulse and a poor or bad general condition, clearly constitute a series of probabilities which, taken together, entitle us to diagnose almost certainly a peritoneal lesion.

All these different indications, however, have not the same demonstrative value.

The most constant is the *rigidity of the abdominal walls*. This has the advantage of being one of the

gravity of wounds of the buttock, which go deeper than the skin. When fragments, especially of shells, bombs, or grenades enter the muscular masses, beneath a cutaneous orifice sometimes little more than a puncture, we find serious damage; muscles pulped, hæmatomata, rupture of the gluteal or sciatic arteries, even detachment of the rectum. If this amount of destruction be compared with neighbouring wounds due to the fragments of the same shell, it would appear that the muscular masses of the buttocks offer scarcely any resistance. Practically we might say "*Bulging wound of buttock, hæmatoma; look out for pulped muscles and gangrene, beware of rupture of the gluteal or sciatic vessels! But with a wound of the buttock without evidence of projectile, flat buttocks, beware of abdominal penetration!*" (See Figs. 41 and 42.)

first symptoms; but it is not really conclusive unless it is general all over the abdomen. If local it only enables one to diagnose penetration when the localisation is some distance from the entrance of the projectile.

Absence of flatus comes second. Every time that a patient is able, after the accident, to expel gas by the anus, one can be positive that there is no penetrating abdominal wound. The contrary is not true, at least in the early stages, and the absence of wind is not sufficient to allow us to diagnose penetration.

Spontaneous pains are a symptom of great probability, but are liable to be slow in developing; when a man is just removed from an ambulance, one hardly knows whether or not to attribute these pains merely to the journey in the automobile. Whenever a wounded man complains incessantly of his abdomen he is almost certainly suffering from a penetrating wound.

From the *general condition* it is difficult to draw immediate conclusions. One slight wound may be accompanied by a grave general condition; with another the pulse and skin are little altered, although there are extrusion of the viscera and extensive wounds of the colon and small intestine. Practically, however, one must own that a bad colour, with weak and sinking pulse, which do not rapidly improve under morphia, are signs of a severe penetrating wound.

Vomiting has little diagnostic value, as it accompanies wounds of the thorax, and head, and even of the limbs. Its persistence or recurrence becomes significant, but only in the later stages.

The same may be said of the *absence of voluntary micturition*. In fact, there are signs suggestive of penetration of which some have a very real significance; *none of them is pathognomonic*, but when taken altogether they are conclusive.

But one must never forget that the whole series may only be roughly indicated or incomplete during the first

hours—that is to say, just when the decision to operate or not may be most useful. And one could not defer the operation in order to wait until they were all developed.

Another cause of mistakes.—All these symptoms, isolated or grouped, may be found with abdominal wounds which are not penetrating. This has been called the "**paraperitoneal syndrome.**"

Our case 1 [[33]] is typical in this respect.

Rouvillois in the case of a wound caused by a small projectile which had entered above the pubic symphysis, observed general abdominal pains with resistance of the walls and slight tympanites; vomiting and pulsation of the nostrils were observed; pulse 120, and a poor general condition. But an operation took away a small shell-splinter from the wall of the abdomen and some bits of clothing; the abdominal symptoms disappeared rapidly.

Jean Quénu [[34]] has collected, in a very interesting study, nine observations of the same kind—that is to say, of parietal wounds with peritoneal symptoms.

But the "paraperitoneal syndrome" may also accompany wounds seated elsewhere than in the abdomen.

First of all, in the loins. And this is often caused by an injury to the genito-abdominal nerves.

In the same way thoracic injuries may lead one to a wrong conclusion. Why should we be astonished? Are we not familiar with false peritonitis, and the false appendicitis which accompanies pneumonia? The same thing happens with injuries, and the following case-report is characteristic in this respect.

A shell-splinter entered in the left axillary line, the width of two fingers above the lower margin of the ribs. The patient's abdomen was painful on pressure, especially towards the right side, and slightly distended, breathing difficult and distressed; no flatus, pulse 88, temp. 37° (98·6° Fahr.) the absence

of vomiting and spontaneous micturition were more reassuring. The projectile was removed from immediately below the inferior costal cartilage. *Neither pleura nor peritoneum was injured.* (Rouvillois [16], Obs. xiv.)

But one may be obliged to perform laparotomy in order to dispel all doubts; Clermont did this at least twice.

The grazing of the wall of the diaphragm by a projectile free in the pleural cavity produced in one of Picqué's patients a general contraction of the abdominal walls, although on one side this was slight.

Finally I will cite a case of my own which is quite exceptional.

Wounded in the lumbar region, the patient complained of violent pains in the abdomen—so violent as to make him cry out; the least touch increased the pains; there was distention; no flatus; no micturition. P. 92; T. 38·2° (100·75° Fahr.). But surgical exploration led to the transverse processes of the second lumbar vertebra; shattered by a shell-splinter which was still in contact with them, they pressed on the posterior fibres of the spinal cord. Thence came the visceral crises which were only one element in a *complete syndrome reminding one of tabes.* After *laminectomy* we observed daily improvement.

Lastly, we must remember that the rigidity of the abdominal walls may be due to injection of antitetanic serum.

To sum up: Diagnosis of penetration is generally easy when we know the course of the projectile, apart from the existence of the abdominal syndrome, but properly speaking a *warning symptom* does not exist.

Rigidity of the abdominal wall is the most trustworthy symptom, especially if it is general; it is the symptom which must be looked for and analysed with the greatest care. The diagnosis may remain undecided. In these cases a direct exploratory surgical examination

is necessary, and, if free opening up is anatomically impossible, an *exploratory laparotomy* may be the last resource; one must not hesitate to employ it. A superfluous laparotomy is not a very serious matter; an unrecognised penetration is only too often fatal.

2. **What Viscera are injured? Is the small Intestine affected?**

It would seem more instructive to pass organ after organ in review and note how each one "proclaims" its wounds. But does the surgeon eliminate organ after organ like this? No! He infers the possibility of the injury of one organ rather than of another, by the actual position of the wound. *A topographical classification guides his investigation.* We will follow the same plan.

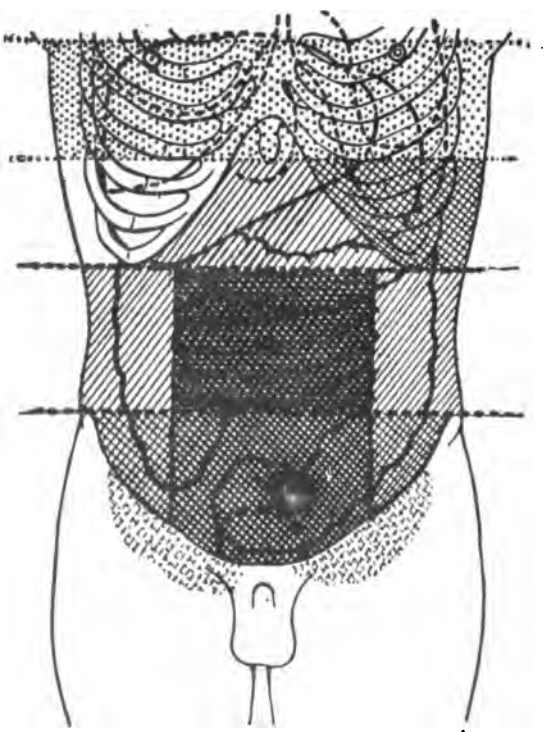


FIG. 43.—Diagram of the abdominal regions. Topographical distribution of abdominal wounds according to their seriousness and their varying tendency to spontaneous recovery. Wounds in the clear or slightly shaded region give the best chance of recovery; those in the darkly shaded region are the most serious.

Here are some cases where the diagnosis is easy. A *visceral hernia* shows at once what lesions are present, such as laceration or wound of the liver or the spleen,

perforation of the stomach, perforations in parts of the small intestine, or of the colon. But it would be a dangerous mistake to suppose that all the injuries received are visible and that a given artificial anus is providential; one will almost always find in the abdomen other and more serious injuries, and it is necessary to make a surgical exploration. In the same way, because the omentum alone is exposed, one must not conclude that there are no internal injuries; only too often there exist deep-seated visceral wounds which need examination, and the plug formed by the omentum, which closes up the abdominal cavity, is neither beneficial nor reliable!

Let us now go back to the diagram which the study of anatomical injuries has led us to adopt and which divides the abdominal walls into regions of varying importance (Fig. 43).

(*a*) A penetrating wound involves the **umbilical region**: one can almost certainly infer lesions of the small intestine and the transverse colon. In this case the transverse colon should be considered separately from the rest of the large intestine; the variations of its level in different patients, its very great mobility, and its exclusively intra-peritoneal situation, make it analogous, from the point of view of the injuries, to a loop of the small intestine. Doubtless there exist verified cases of projectiles having traversed the umbilical region from one end to the other or having remained loose in the abdominal cavity without any injury being done to the intestine. Wallace's diagram furnishes examples of these, on which we have already dwelt in Chapter IV. (see p. 338). But such cases are so exceptional as to be practically negligible. It would be subjecting the patient to too great risks if one dared to refuse to operate because of the possibility of such a providential coincidence; only the most complete absence of all abdominal

symptoms would justify such action. That is to say, it would hardly ever occur!

As a matter of fact, injuries in the umbilical region are regularly accompanied by a typical peritoneal syndrome, generalised pains, parietal rigidity, stoppage of fæces and wind, vomiting, and rapid and feeble pulse—that is to say, all the symptoms which we have shown accompany penetration.

If certain of these are accentuated it enables us sometimes to conjecture the seriousness of any given visceral wound. Continuous and intense *spontaneous pains* often accompany extensive laceration, actual section, or many perforations of the intestine. *General rigidity* of the whole abdominal wall, with heavy expirations (as if the patient "was sawing wood") indicate severe visceral wounds sometimes accompanied by great loss of blood.

Absence of flatus is almost constant.

Repeated vomiting is an unfavourable symptom. But, above all, it is the pulse that one must watch; its frequency up to 120 and above, its low tension, its intermittence, especially if the face is pale and the features drawn. These are all indications of a serious wound.

And if these signs persist after the pain has been subdued by morphia, the diagnosis is quite clear.

Temperature is of no special importance unless very low or very high; 36·5° or 39·5° (97·7°—103° Fahr.) are new indications of gravity. From a temperature of 38·5° (101·5° Fahr.) one can deduce nothing.

Prehepatic resonance is a well-known indication of intestinal perforation with free gas; it is, however, of very rare occurrence. If, however, the causes of the wound are known, then the rigidity and pain would make this sign unreliable.

The same is true of the *dullness of the flanks and iliac fossæ*, which is a logical but frequently absent sign of extravasation and hæmorrhage.

In one case of a wound in the small intestine Schwartz and Moquot detected a sort of *splashing* in the right iliac fossa.

With the exception of this symptom and the pre-hepatic resonance, other symptoms are those of simple penetration.

To sum up: In practice a penetrating wound in the umbilical region will always be supposed to have injured the small intestine, or the transverse colon, either alone or associated with other viscera. And, without operation, the prognosis will always be considered hopeless; even after operation it is still very serious.

(*b*) The **hypogastric region,** with the inner parts of the iliac fossæ, comes second as regards gravity. Here, again, it is the small intestine which is very frequently injured. The seriousness is a little less because the pelvis, "the main drain," is nearer, and gives occasionally opportunities for spontaneous localisation. But here, too, we find the peritoneal syndrome as in the umbilical region.

In the neighbourhood of the pubes the *bladder* should be suspected. A urinary fistula may very quickly develop. But, as a matter of course, if the patient cannot pass water the *bladder must be catheterised*, and the character of the flow noted. Bloody, red urine, sometimes containing clots and passed with difficulty, indicates a small but not gaping perforation of the bladder.

A slow, frothy flow of blood mingled with urine, or one which falls drop by drop like the discharge from the ureter, indicates a large wound of the bladder which drains into either the pelvis, the region round the rectum, or the rectum itself.

One must also make an *examination of the rectum*, for the rectum is very frequently injured, either in the peritoneal portion or lower down.

The usual position of the ilio-pelvic colon is in the

left iliac fossa, near the median line. Here, again, the colon presents the same features as we have seen in the transverse colon. Its position as an intra-peritoneal organ varies according to the patient and its state of mobility. Hence the seriousness of its perforation, all the more so because the contents of the colon are very highly septic. One fairly frequent symptom is the *red stool*—after abundant evacuation; but this is slow to appear, and is not of any great practical value.

To sum up: An injury above the pubes suggests a perforation of the bladder, of the rectum, or a loop of the small intestine; an injury in the upper part of the hypogastric region, or the iliac fossæ, suggests the small intestine and the colon, more especially the ilio-pelvic colon. These wounds have a very grave prognosis with or without an operation; as a matter of fact, one should look upon them as quite as dangerous as those of the umbilical region.

(*c*) **The flanks and the outer parts of the iliac fossæ** represent the vertical boundaries of the regions of the colon. Here a very clear distinction can be made between the different kinds of injuries.

A tangential breach with gaping lips and lateral perforation of the colon forms a traumatic false anus, of slight gravity. A lateral and oblique tunnel wound with entirely localised symptoms and with no involvement of the general condition leads one to conjecture an extraperitoneal perforation of the colon: prognosis favourable. The same is true when a single very lateral wound produces no abdominal symptoms.

But a wound with only one orifice accompanied by abdominal symptoms, or a wound near the umbilical region, ought to be considered as penetrating the viscera and as serious wounds because they lead either to the small intestines or to the colon in its free peritoneal portion, and also because here there is a danger of highly septic matter finding its way into the abdomen.

(*d*) The **upper part of the abdomen** comprises three parts.

The right hypochondrium is the region of the liver; every penetrating wound in this region will certainly injure it.

The left hypochondrium is occupied by the stomach, the spleen, and the upper end of the descending colon. The central epigastric triangle leads on the right to the liver and the gall-bladder, on the left, to the stomach.

Are there any absolutely sure symptoms of *hepatic penetration*? The continuous oozing of dark blood is strong presumptive evidence; a discharge of bile immediately or during the next day or two is a positive symptom.

With regard to the *stomach*, local pains and vomiting are frequent, but not constant; hæmatemesis is a positive symptom, but is rather unusual.

Perforation of the *spleen* produces no other symptoms than hæmorrhage. Generally speaking, one may consider that penetrating wounds of the upper part of the abdomen have a favourable prognosis.

Quénu only considers as benign wounds whose course is quite above the horizontal line of the costal margin. Certain reservations, however, must be made.

As regards the stomach, there is danger of escape of fæces into the main abdominal cavity; if the wound occurred soon after the patient had taken food, the stomach would be distended and there would be signs of general peritoneal reaction. There might be danger, also, of double perforation with hæmorrhage in the posterior cavity of the omentum (the diagnosis is difficult, but is suggested if there are indications of hæmorrhage and sharp, deep-seated pains, with increasing swelling in the sub-gastric region), or there might be actual section of the vascular ligaments of the stomach, or of the arteries which surround it (signs of hæmorrhage). In the case of the liver and

spleen, the danger arises from profuse and prolonged hæmorrhage.

In the case of all these organs a common cause of aggravation is the existence of injuries to other hollow viscera, such as the transverse colon, or the small intestine, or to the large blood-vessels.

From all these contingencies, and from the anatomical characters which differentiate the liver, the spleen, and the stomach (fixedness of the first, friability and mobility of the second, the hollow nature of the third), it follows that, generally speaking, wounds of the left hypochondrium are more serious than those of the right, and also equally more serious than those of the epigastric region.*

But here we note a very common complication of penetrating wounds in the upper part of the abdomen to which we attach great importance; that is, the co-existence of thoracic injuries. *Thoraco-abdominal wounds* are found under two very different conditions.

The passage of the projectile through the abdomen has not produced any serious injuries; there is neither a large wound, nor visceral hernia, nor symptom of intestinal laceration, nor sign of hæmorrhage; the whole diagnosis is dominated by the thoracic

* An autopsy happens to demonstrate an anatomical arrangement of the parts which shows how variable are the relations of the gut to the parietes. Examination of two photographs of Plate I, shows that, in certain subjects, the transverse colon descends to the neighbourhood of the umbilicus, or even below it, and that numerous coils of small intestine may be found beneath the transverse colon. The photograph, which represents the transverse colon held up, shows clearly three coils of small intestines situated to the left between the stomach and the still visible bed of the transverse colon on the intestinal mass. We see, therefore, how illusory is the topographical barrier of the "colic frame"! It should further be noted that, in this subject, the colon is nowhere sessile, but furnished in its vertical portions with a meso-colon at least ten centimetres long. Besides, the transverse meso-colon was adherent to the omentum between the colon and the stomach, thus realising the diagram in Chapter VIII. (p. 506. The resulting layer, not very thick, would render impossible the method proposed by Pauchet for reaching the lesser cavity of the peritoneum.

symptoms. While considering these one neglects the abdominal injury; it is a thoracic wound one has to attend to and not an abdominal one.

The prognosis is that of a penetrating wound of the chest.* But there is strong presumption in favour of an intestinal perforation, or of a serious gastric laceration, or of severe hepatic or splenic hæmorrhage; the immediate danger is to the abdomen. And therefore we know at once that the prognosis is always extremely serious.

It is more serious still when the injuries are widespread and the wound gaping, in the thorax as well as in the abdomen (see p. 380). We must be on the look-out for *visceral hernias through the diaphragm.* When a thorax wound has closed up, these hernias may be cured or may require operation at a later stage,† but if the opening in the thorax is large, or if there is strangulation at the diaphragmatic orifice,‡ death is almost certain.

* Chaput ([15]) mentions examples of thoraco-abdominal wounds benign in appearance, but which nevertheless required a pleurotomy for infected hæmo-thorax, and, later, an opening through the diaphragm for sub-phrenic abscess. Doubtless, a wound which is at the same time thoracic and abdominal has a perfect right to develop as a thoracic injury and cause a hæmothorax which nothing can prevent from becoming infected, and to evolve as an abdominal wound and determine a collection of pus which is only a process of recovery. This shows that such cases need closely watching in both stages; but, from the point of view of immediate treatment, we cannot conclude from it that a laparotomy has preventive utility; and we do not agree with the advice which Chaput gives, to make a systematic exploratory laparotomy in order to verify the fact of penetration.

† Four months after a bullet wound Duval ([63]) performed resection of the seventh rib, which had been fractured and consolidated; the omentum which was found beneath the skin adherent to the parietal pleura, was caught in an opening in the diaphragm 2 cm. long by 5–6 cm. wide; after partial resection it was replaced in the abdomen through the orifice in the diaphragm; the splenic angle and the spleen were found adherent to one another; the spleen seemed to have been perforated by a bullet. After suture of the diaphragm, the thorax was completely closed, and the air in the pleural cavity aspirated. Complete recovery.

‡ See our cases (Figs. 20 and 21) and that of Legrain and Quénu, whose drawing we have reproduced (Fig. 22).

PLATE I

FIG. A.—Abdomen widely opened, the organs *in situ*. Between the stomach and the transverse colon, the omentum and the meso-colon tightly joined together, form a thin veil through which are seen several loops of the intestine situated high up.

FIG. B.—Same subject: the colon has been raised; the curved depression of its "bed" across loops of small intestine is seen; above are three projecting loops of small intestine. Subject was ptosic, with all the mesenteries elongated and pedunculated.

(*e*) The **lumbar region** gives access to the kidneys; hæmaturia is very frequent; as a rule it quickly diminishes; but abundant flow, its persistence, painfulness, and signs of increasing hæmorrhage, suggest rupture of the kidney, always a most serious injury. Projectiles which enter through the loins often damage the whole intestinal viscera, both small intestine and colon. We must remember this when we find abdominal symptoms.

As a rule, injuries in the lumbar regions are not so serious.

(*f*) Quite the contrary is the case with **injuries to the buttocks**. All penetrating abdominal wounds through the buttocks are very serious indeed. The projectiles may injure the bladder or the rectum, or may break the sacrum or the iliac bones, all of which lie close together in the same horizontal plane. There is every cause for grave prognosis. Entering by an oblique vertical line, the projectiles go straight into the whole intestinal mass to cause numerous lacerations and perforations throughout it. Death is almost inevitable. (See Figs. 41 and 42.) All these wounds ought to be examined with great care, the bladder must be emptied and the rectum examined. Openings near the sacrum or in the neighbourhood of the anus can conveniently be examined in the position advocated by Depage—that is to say, like an inverted V (Λ), the head and legs hanging down, and the sacrum upwards; this position gives the best light.

B. Therapeutic Indications

Now the moment for a decision has arrived. The course to follow is determined by the examination we have just made, and by the estimation of the seat and probable nature of the injuries to the viscera.

But there are still two factors which may intervene,

although they are of less importance: (1) the general condition of the patient, (2) the nature of the projectile.

Let us then consider the therapeutic indications from the point of view of the wound, the patient, and the projectile.

1. **As regards the Wound.**—There are cases where an operation is absolutely essential, others where it is equally clearly forbidden, others where it is doubtful.

(*a*) *Cases in which operation is imperative.*—Laparotomy is advisable for all penetrating abdominal wounds with visceral hernia or hernia of the omentum only.

In all cases of wounds in the umbilical region (there is one very rare exception, *i.e.* when there is absolutely no sign of abdominal reaction).

All injuries of the hypogastrium and of the inner wall of the iliac fossæ (one rare exception is that of a small supra-pubic wound with lateral or closed vesical lesion); all deep-seated abdominal wounds through the buttocks; injuries to the flank adjoining the umbilical region, whether directed forwards to the umbilicus itself, or simply suspected to be intra-peritoneal, and wounds in the lumbar region with abdominal symptoms. In all these cases the surgeon should have no hesitation.

(*b*) *Cases which should not be operated on.*—These are wounds which are almost certainly non-penetrating on account of their position and of the complete absence of abdominal reaction.

Thoraco-abdominal wounds without serious injury to the abdomen.

Wounds of the right hypochondrium without severe hæmorrhage. Small epigastric wounds without symptoms of reaction or signs of hæmorrhage.

Lateral wounds of the various colic regions with closed orifices, with no reaction, or gaping largely and letting the intestinal contents flow away freely—

that is to say, almost solely tangential wounds outside the peritoneum.

In my opinion these are the only cases where one should deliberately avoid operation.

(*c*) *Doubtful Cases.*—There is every reason to hesitate in the following cases :

A wound probably not penetrating, but with the peritoneal syndrome. Penetrating wound of the stomach.

Wound in the left hypochondrium.

In each of these cases laparotomy runs the risk of being useless or even injurious.

To solve these doubts by means of a clinical examination alone will often be impossible, and here temperament and individual diagnostic instinct come in.

Rouhier, for example, always tries to avoid any unnecessary laparotomy, and the benefit of the doubt in his case would lead rather to a decision not to operate ; others, on the contrary, and these are the majority, judge by averages and think that mistakes are likely to prove more costly if they lead to abstention, after which nothing can be done, than if they lead to an aseptic laparotomy steadily carried out.

Here are two cases, amongst others, where the balance is in favour of operation : a penetrating but small wound in the stomach in the case of a patient who had just had a meal ; and a penetrating wound of the left hypochondrium with slight symptoms of reaction or signs of hæmorrhage. In all other cases the prescription most advantageous to the patient appears to us to be, in war-time as in peace : *When in doubt, operate ! if you hesitate, perform laparotomy !*

2. **As regards the Patient.**—Should one operate on all patients with abdominal wounds having regard only to the nature of the wound and whatever be the general condition of the patient ?

Both theories have their partisans.

Certain surgeons have always systematically per-

formed, laparotomy for all penetrating wounds, however desperate the case might appear. There was a reason for this: it was necessary to be able to contrast the total results of one method with the results of another, and thus to learn by experience the most extreme limits when laparotomy could effectively be used. At the present moment opinion is clear on these two points, and we can legitimately *set aside the cases which are clearly beyond surgical aid.* Extensive injuries with many lacerations or actual sections of the intestine, wide-spread tearing of the mesentery, blood and fæcal matter in the abdomen, leave no hope of a cure; the same is true of large thoraco-abdominal wounds with or without visceral hernia and extensive visceral extrusions above or below the umbilical region. It is to the interest of the other patients not to waste time, at their expense, in attempts which one knows cannot produce any satisfactory result, and it is also merciful to allow these poor fellows to die in peace under the influence of morphia.

The same thing is true of *old wounds* which date back at most thirty-six hours. From about the twelfth hour, the chances of cure by laparotomy decrease hourly very rapidly. After twenty-four to thirty-six hours any chance of recovery exists only in exceptional cases, which examination may show are not already rendered hopeless by a rapidly developing peritonitis.

But, this period once passed, one must acknowledge that there is only room for two types of wounded: those with acute general peritonitis, and those whose lesions show signs of local reaction only and still have some chance of spontaneous recovery. For either case laparotomy is at best useless, and more often than not will be injurious.

In these cases *Murphy's operation* may be useful. If we have refused to compare this with laparotomy as the special treatment to be preferred, we ought

in justice to remember that it has produced some pleasant surprises (Didier, Murard). And it will be justifiable to use Murphy's supra-pubic buttonhole for penetrating wounds of the abdomen more than about twenty-four hours old and in which the clinical examination does not promise a favourable result.

But it is on the question of **shock** that the advocates for or against immediate operation chiefly disagree.

Shock is characterised by: a rapid, weak, and even uncountable pulse, paleness of face, with nose cold and drawn, sunken eyes; general coldness of the body, but particularly of the extremities; mental torpor, with resigned euphoria, or, on the contrary, excitement and loquacity.

Its frequency varies according to the different conditions of the sections of the front line, perhaps also according to the interpretation of the surgeons. Amongst our wounded, evacuated from a distance of 12 kilometres, we observe it very often, especially at night. Sencert also notices this point.

Shock is by no means confined to wounds of the abdomen, but often accompanies serious injury to the limbs, such as high amputations of a limb or numerous and bilateral wounds of the lower limbs. There is no question here of peritoneal infection as a cause.

Anæmia, considered as the only cause by Cotte and Latarjet, and Bouvier and Caudrelier, was perhaps the predominant cause of shock in the case of wounded brought in immediately and not carried for several kilometres, and getting chilled on the journey.

But, amongst the wounded whose cases we are considering, there would seem to be little connection between the intensity of the shock and the seriousness of the deep-seated injuries.

Besides hæmorrhage, nervous shock certainly comes into play (intensity of the injury, previous emotional exhaustion, the shaking up of the abdominal viscera during the automobile journey over rough roads).

Hæmorrhage which is not severe enough to prevent a patient being carried for a distance of 12 kilometres is never so bad that it cannot be temporarily checked by injections of saline and adrenalin (otherwise the patient will die during or immediately after the operation). On the other hand, the nervous shock will undoubtedly be lessened by the tonics we have mentioned.

Here, then, is our programme: immediate injection of camphorated oil, ether, even of morphia if the patient is in great pain, but above all a copious injection of saline with 1 milligramme of adrenalin; if intravenous injection seems advisable, use at least a litre; shivering and shock will not be more marked than

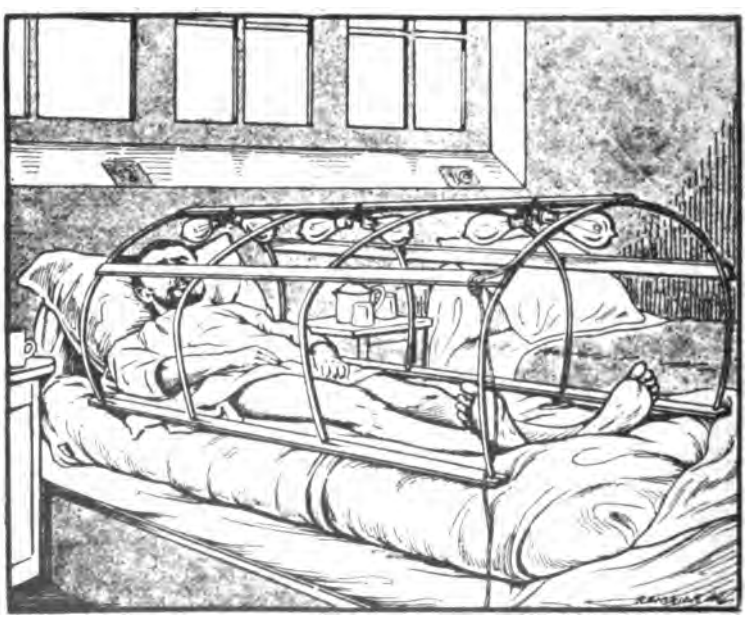


FIG. 44.—Simple apparatus with electric lamps for warming patients when suffering from shock (lamps with carbon filaments).

with a small injection, and it has the advantage of keeping the blood vessels full. Then, if within an hour

the patient does not begin to improve, no operation is likely to be in time to be successful, either on account of hæmorrhage too severe to be checked, or because of the nervous shock from too great a "nervous hæmorrhage." If, on the contrary, the pulse becomes stronger, and the patient begins to improve, one may operate without further delay; but the subcutaneous injection of saline must be continued during the operation.

FIG. 45.—Stretcher for warming patients. (Poucel [88].)

This, then, is the method which we follow for severe wounds to the limbs; often after some hours' rest an extensive operation for the removal of splinters, or even an amputation of the thigh, becomes possible and may do well; which would have caused immediate death if the patient had not been rested, warmed, and revived.

We reproduce here two models of apparatus for warming a patient; one (Fig. 44) uses electric lamps (we had one made quite easily in our ambulance); the other (Fig. 45) employs petrol or methylated spirit, and so can be used anywhere.

3. **From the Point of View of the Projectile.**—It is generally admitted that *bullet-wounds* are less serious than those from *shell-splinters*, but in the list of the first 15 cases which we published were found: 4 bullets with 3 deaths and 1 recovery; 11 shell-fragments with 6 deaths and 5 recoveries—figures which

would seem to prove the greater seriousness of bullet-wounds. This explains itself. In our section of the line there is hardly ever any open fighting, it is a struggle between trenches very close together; bullet wounds, therefore, are very rare, and such as occur are usually very severe on account of the short range.

The main thesis, therefore, is still correct, but one must not try to draw too precise therapeutic deductions.

To know that a wound has been caused by a *bullet* will doubtless strengthen the decision already taken not to operate when the case is already following a normal course, but will never cause one to refrain from operating when operation is plainly indicated by the clinical examination.

On the other hand, even a small *shell-splinter* which is almost always irregular and mixed up with pieces of clothing makes an operation still more imperative.

To sum up: The *nature of the projectile* adds confirmatory evidence to that already obtained from an examination of the patient, but is never decisive when considered alone.

This is true also of its *size.* The seriousness of deep-seated wounds is never in proportion to the size of the projectile, nor is the importance of the injury done in proportion to the size of the wound where the projectile entered; one ought not, therefore, to follow the examples of Gosset or of Pellot, who vary their methods according as they are dealing with a small or a large projectile.

Radioscopy

There has been no mention in this chapter on diagnosis of the help to be obtained from X-rays. This is intentional.

Not all army surgeons have a radioscopic equipment under their control; most of them have only at their disposal from time to time, and for a short period, a

travelling radioscopic unit which pure chance may bring their way at the moment when an abdominal wound is being examined !

In times of pressure, even with a permanent equipment, the surgeon will often be obliged to decide on an operation without having time to use the X-rays at all.

Then the clinical examination must suffice him ; so it is on this alone that we have based our observations in the preceding pages.

Are we to conclude, then, that in the diagnosis of deep-seated abdominal wounds X-rays may not play a very important part ? Certainly not. For it gives us additional information of a very exact nature in all those cases which we know to be most difficult of diagnosis : *those wounds with only one opening.*

In determining the site of the projectile, the radioscope shows also in the simplest way the course of such a projectile of which we know the openings both of its entrance and exit. Still further, it shows us the shape and size of the projectile. Sometimes, indeed, it shows us that a projectile supposed to be embedded in the tissues has really gone straight through the body.

Thus the radioscope helps us more easily to answer the two questions which sum up the whole clinical examination : Is the wound penetrating ? Is there a visceral injury ?

Here, for instance, is a case where the X-rays had helped to confirm a hesitating diagnosis :

April 20th, 1916, R—— had three small penetrating wounds at the base of the left thigh, another on the crural arch, another under the left anterior superior iliac spine.

Pains in the abdomen. T. 38° (100·4° Fahr.). *But* the pulse (92) was strong ; voluntary micturition ; two stools, of which one was copious ; skin normal ; localised pain in the right iliac fossa.

The radioscope showed us at once that the projectile was not in the abdomen, but on the left iliac margin.

There was no operation, and uninterrupted convalescence followed.

Note that the clinical examination alone had already made us decide not to operate; the X-rays only gave us additional confidence.

In one of Rouvillois's cases they gave greater corroborative evidence; the clinical examination led one to consider the possibility of operating for a wound in the lumbar region complicated by hæmaturia with great rigidity of the abdomen; under the X-rays a tiny shell-splinter was discovered moving up and down with the diaphragm; no operation was performed, and the patient recovered.

Such cases are fairly exceptional at this stage, and the radioscope can only modify the indications of the clinical examination if these are rather doubtful, and if the situation of the projectile in and moving with any organ is clearly indicated.

For the known depth of the projectile does not allow us to state that it is actually inside the abdominal cavity. One has often a very false idea of the thickness of the walls of the whole posterior part of the trunk in comparison with the total thickness of the body, and one often believes the projectile to be right inside the abdominal cavity when it is really in the posterior muscles. (See Fig. 39.)

With regard to this, case 676 of Chevassu is interesting: because a projectile, protruding from the left margin of the image (on the screen) of the fourth lumbar vertebra, was 9 cm. from the anterior wall, the total thickness at this level being 20 cm., one was inclined to conclude that the projectile was in the small intestine. It was, on the contrary, much more probable that it was in the posterior wall, because the vertebral column is not 9 cm. from the walls in a subject whose diameter is 20 cm.!

But there is still more to be said. A projectile may be found on a plane the depth of which places it really

within the confines of the abdominal cavity, and yet it is not *intra-peritoneal*. We note the following example.

B——, April 26th, 1916, besides many other wounds, had a *penetrating wound in the right lumbar region*, with neither hæmaturia nor abdominal symptoms. Medical treatment.

The radioscope showed, next day, a shell fragment 4 cm. long, projecting on the right side of the umbilicus on a diagonal reaching the hypochondrium and 8 cm. in depth from before backwards.

On May 2nd there was a copious discharge from the posterior orifice, a clamp was cautiously introduced in a posterior-anterior direction, and at a distance of 14 cm. from the aperture the projectile was felt and taken out carefully (Fig. 46); it was accompanied by shreds of clothing. Recovery normal.

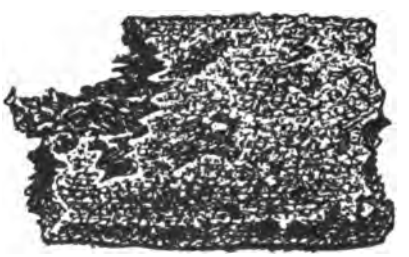


FIG. 46.—Splinter of shell situated 8 cm. from the anterior walls and at the same time extra-peritoneal. (Case B, p. 473).

This projectile, therefore, was right inside the abdomen, but it was certainly neither intravisceral nor intraperitoneal; very probably it had split the mesentery or the transverse colon! Therefore, whatever may be the mathematical precision given by the radioscope, the interpretation of what is seen still leaves an inevitable opportunity for error. And *when there is disagreement between the clinical examination and the radioscope, we give precedence to the former.* Rouhier [28] arrived at similar conclusions.

What will be the best *methods of localising intra-abdominal projectiles?*

It is generally sufficient to localise the depth from a fixed point marked on the parietes.

All the methods suggested by the double projection

on the screen, after moving the X-ray tube, are acceptable. The method of Haret, the "planchette" of Hirtz, the "skiamètre" of Vialet [62], etc., all give rapid indications.

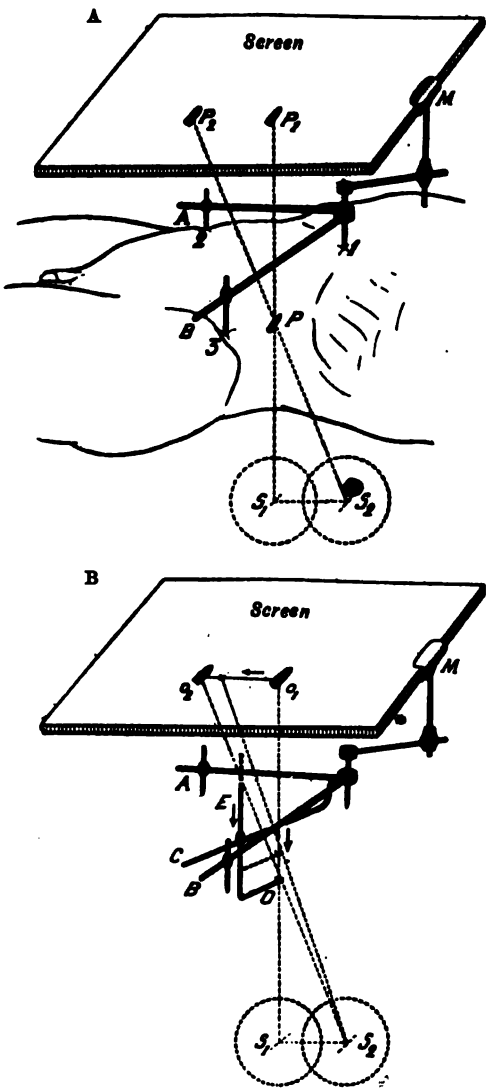


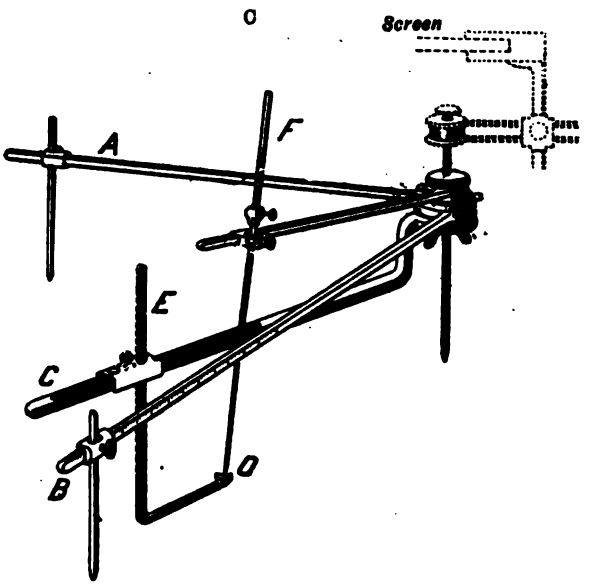
FIG. 47.—Surgical compass, with direct controls under the X-ray screen. (The author's invention, patented.)

Such circumstances as mobility, with the respiratory movements and induced movements, help the anatomical diagnosis of the position of the projectile.

We give here a surgical "compass," of our own design, which has the advantage not only of giving very rapidly on the screen, without any calculation or tables, the depth of the projectile (a fixed point of the apparatus attached to the screen is substituted in the place previously occupied by the projectile), but also of being adjusted directly under the screen in such a

way as to allow, if necessary, an exact localisation of the projectile during the operation. A short description of the method of using the apparatus (see Figs. 47 and 47 *bis*) is sufficient.

(1) The patient is placed under the radioscope, the existence of the projectile verified, and the approximate situation determined by a right-angled projection.



(2) Three guiding surface-marks are noted on the skin, the three points of the compass are placed in contact with these (position *A*), and a first right-angled projection of the projectile is marked on the screen. A second projection is marked according to the known displacement of the tube. The patient is then taken away.

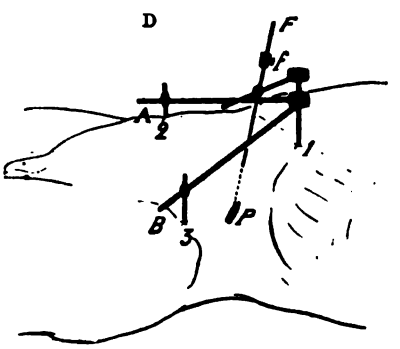


FIG. 47 *bis*.—Surgical compass, with direct controls under the X-ray screen. (The author's invention, patented.)

(3) The bar *C* (position *B*) is placed in the compass. The X-ray tube being placed in the original position, the image of *O* is brought to coincide with the first

image of the projectile, the X-ray tube is displaced as before; the bar *E* is lowered until the image of *O* coincides with the second image of the projectile. *O* clearly occupies in relation to the screen the same position in space which was originally occupied by the projectile; further, the image thus directly corresponds to the three points of the fixed compass—that is to say, with the three guiding surface-marks on the body.

(4) If we now bring the point of the indicator into the socket *O* (position *C*) and if we take away the arm *C*, now unnecessary, the compass is arranged for the surgical operation and the examination of the projectile (position *D*).

If we note the eight figures which determine (1) the space between the arms, (2) the position of the one point, (3) the position of the other point, (4) the position of the socket *O*, we can at any moment remove the compass or replace it just as it was before.

The procedure is still shorter if one simply wishes to measure the depth of the projectile. The arm *C* being in position over the patient, we place *O* on the skin, projecting it on to the screen at the same point as the projectile in the right-angled position; we note its height on the scale; then we proceed as above (2) and (3). The distance between the two positions of *O* give the position and depth of the projectile from the skin.

. . . . .

Conclusions.—The multiplicity of cases we have considered, all of which were necessary for the complete discussion of the problem of diagnosis, may have the disadvantage of misleading us as to their relative importance and of leaving on the mind an impression of a confused and indecisive clinical examination, just where, on the contrary, we must have a very clear, and definite idea of the course to be followed.

We therefore think it wiser to correct this analytical

examination by a general summing up. Our conclusions are as follows:

(1) In the majority of cases, the character of the wounds and the clinical syndrome indicate deep-seated wounds of the abdomen and viscera; laparotomy must be performed. The only cases in which we decide not to operate (which we have already discussed) demand such a complete knowledge of the course of the projectile that they are exceptional, and can hardly occur unless there are two orifices, one of entry and one of exit, or an orifice of entry and localisation by the radioscope of the projectile.

(2) A single abdominal wound, wherever it be, calls for operation, unless there is complete absence of abdominal symptoms.

(3) A small wound does not mean that the lesions are negligible. Too often, on the contrary, one finds that they are extensive and serious.

(4) Resistance of the abdominal wall and the pulse are the most useful symptoms for confirming the need for operation and guiding the prognosis.

(5) It is never admissible to put off the diagnosis or the special treatment: "watchful expectation is a meaningless expression" (Quénu).

A superfluous exploratory laparotomy is preferable to the risks of delay.

Hesitation in diagnosis must not mean hesitation in the treatment, *for, if one hesitates, it is clear that operation is necessary.*

CHAPTER VIII

LAPAROTOMY FOR PENETRATING WOUNDS OF THE ABDOMEN

LAPAROTOMY for penetrating wounds of the abdomen is the type of operation which ought to be conducted rapidly, and it should be simple and methodical: *simple* as to its equipment and the choice of its technical procedure, and *methodical* in its execution; for, even when performed under unexpected conditions, a strict and almost invariable plan should be followed.

Preliminary surgical examination of the openings with treatment of any hernia which may be found;
Laparotomy properly so called;
Rapid inspection or exposure of the principal seat of the lesions;
Treatment of these lesions;
General overhauling of the other viscera;
Cleaning up and draining of the peritoneum;
Suture.

We will now review these various processes.

Instruments and Material.—The following are sufficient (see Figs. 48 and 49):

1 scalpel.
2 pairs of scissors (one for aseptic, the other for septic use);
3 dissection forceps (2 aseptic and 1 septic);
1 curved needle with handle (Doyen's pattern);

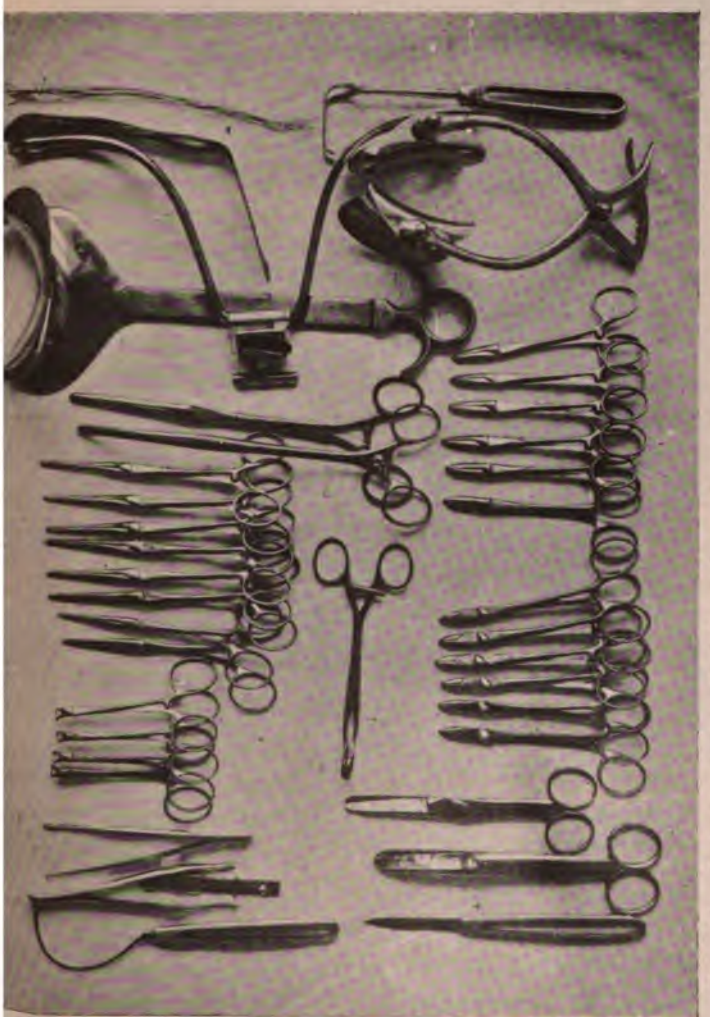


Fig. 48.—Instruments needed for a laparotomy for penetrating wound (first set).

12 Doyen's short-bladed forceps (or 6 Doyen and 6 Terrier) ;
8 Kocher's forceps * ;

* We give these different types of forceps because they are supplied by our medical service ; in our personal practice for many years now we have used only one kind of forceps—that of Delagénière.

2 long hæmostatic clamps (these will serve, as a rule, to carry the swabs to the deep parts and to fix the drainage-tubes, but they will be equally valuable should we be obliged to clamp a renal or splenic pedicle) ;
6 bowel forceps* ;

FIG. 49.—Instruments reserved for intestinal work and placed upon the small transverse table (second set).

4 intestinal forceps with handles (Chaput's pattern) ;
1 Doyen's sub-pubic valve for placing between the thighs ;
1 self-acting retractor† for the abdominal wall ;

* The simplest are Hartmann's *straight* elastic clamps ; those issued by the Service de Santé are Doyen's curved clamps ; very convenient for the stomach, they are, for the intestine, unnecessarily long and not conveniently curved. Their curvature is not sufficiently long to isolate a segment of intestine and allow the suturing to be done ; it is inconvenient for the approximation and parallel alignment of the intestinal segments.

† The tri-valve model of the Service de Santé has two great

1 valve (Legueu's pattern) or a metallic tongue-depressor; (for certain recesses, to lift up and inspect the posterior surface of the bladder by gently slipping the instrument above its folds);

1 strong double-hooked retractor (Ollier's pattern) *;

6 sets of 2 straight sewing-needles preferably threaded two together at each end of the same loop of thread; this should be 50 cm. long; these needles are stuck into a little roll of gauze and the loop of thread is rolled round it; if we pull the end of the loop, everything unrolls evenly. These sets of needles are sterilised with the dressings or by themselves in separate tubes. (The loops of thread with two needles reduce to a minimum any delay or stoppage in order to re-thread the needles. If we should want a needle threaded on a single thread, nothing is easier

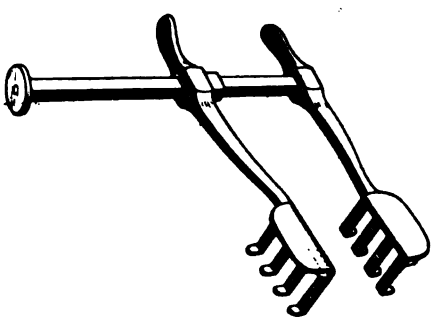


FIG. 50.—Autostatic retractor (author's pattern).

disadvantages; it is not fixed, and turns round. The heads of the screws which adjust the valves catch up compresses and sutures. Much more simple and stable is Gosset's autostatic retractor, large size, or that supplied by Gentile, which is seen on the right in Fig. 48.

For exploring small parietal lesions or exploratory laparotomies, we are accustomed to use the autostatic retractor which is represented in Fig. 50. We have always employed in general surgery, in laying open wounds, ligaturing, and cranial trephining. By its aid we can systematically do anything, except laparotomies and some of the more delicate ligatures (carotid, sub-clavian, etc.).

* Or Hartmann's S-shaped retractor, of steel wire.

than to cut the loop and two separate needles are ready);
2 cylindrical curved needles;
2 curved triangular needles for stitching in the

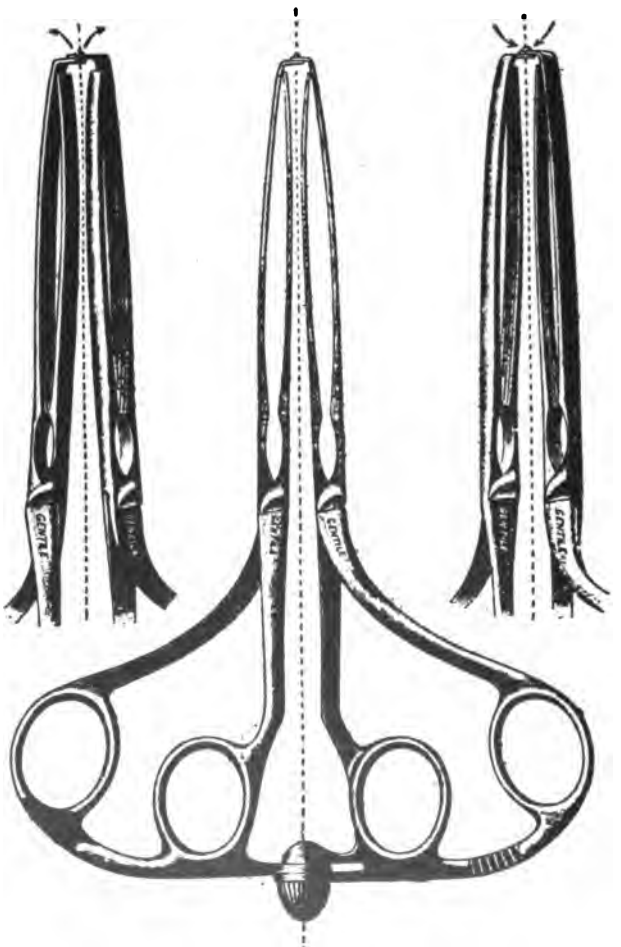


FIG. 51.—Double clamps, permitting different positions, for entero-anastomoses (author's pattern).

deeper parts. (Inserted in one of Doyen's short-bladed forceps they enable one to do

without special-handled (*Aiguilles à pédale*) needles. These are rarely used, however, if we know how to make the usual sewing-needles and needles with a handle serve our purpose).

Metal wire previously cut into lengths of 20 cm.

One can add if desired :

1 heart-shaped forceps (to seize a particular organ, notably the bladder in order to expose the posterior side) ;

1 double forceps for intestinal anastomoses ; Témoin's forceps, for example. We show here a new model of our own, which has the advantage over that of Témoin of allowing for varying obliquity of the area of grip of the forceps, and therefore makes it easier to do the suturing of the posterior serous surfaces without being disturbed by the mass of overlying intestines (the forceps are placed in the position shown on the left) and to do the same for the anterior serous surfaces without straining the tissues (here the forceps are placed in position shown on the right, Fig. 51). These double forceps save a great deal of time when used for lateral anastomoses, they give absolute stability to the parts which have to be joined together and also complete bowel closure ;

1 forceps (Liston's pattern) or one sharp cutting-forceps for dividing the metal wire; the scissors will be all the better for this !

These instruments are divided into two sets, of which one is reserved for use in the intestinal regions, and is placed on a little T-shaped table which can be drawn across the legs of the patient ; by this arrangement one secures great security and rapidity. By the side of the assistant there are some forceps, an Ollier's retractor, and some swabs ; that is all. (See Fig. 30.)

It is necessary to have two or three *large swabs*, 0·75 mètre square; soaked in hot saline, these cover over and support the loops of the intestine during the operation; they are useful also for shutting off the different sectors of the abdominal cavity.

We also employ medium-sized swabs from 0·20–0·25 mètre and others from 0·10 mètre square and in four thicknesses. These two last types will be found in the medical outfit.

For making *sutures* I use only linen thread or fine silk, which slips more easily and holds well; for needles, ordinary sewing-needles. For intestinal surgery catgut is either too fine and too rapidly absorbed or too coarse for the needle to make rapid fine sutures which will not injure the tissues.

As a matter of course, one must operate in rubber *gloves*.*

Pre-operative Precautions.—These consist in the treatment of the wounded for shock (which we have described above) in cases where the operation is delayed for varying periods. In other cases, as a matter of course, we prepare 10 cc. of camphorated oil, ½ cgm. of morphia, some adrenalin or not according to the blood pressure, and we operate as a rule with a continuous hypodermic injection of saline.

The patients are carefully covered, wearing woollen operation stockings and a thick flannel vest.

Anæsthesia.—*Spinal anæsthesia* is not advisable. The conditions here are not comparable to those in ordinary surgery, the patient habituated to the thought of an operation, reassured as to spinal anæsthesia, by the conversations of the nurses or of other patients, the topographical extent of the operation already

* Generally speaking, I have never understood the uses of cotton gloves; when they become soaked with blood, they cannot isolate the tissues; when soaked with pus, they disseminate infection and contaminate the surgeon's hands. This never happens with rubber gloves, which keep the sensitiveness of the finger-tips intact.

known, etc. Here, on the contrary, the patient has only just come out of the hell of actual fighting; one cannot ask of him either the calm necessary for the success of this form of anæsthesia or the effort necessary to acquire and maintain such a calm; further, we have a patient already in a depressed state from anæmia or shock, and spinal toxins have a well-known depressant effect. Besides, we do not know the extent of the injuries; we may have to work up to the diaphragm and even above it; this would necessitate large doses or high injections, and therefore dangerous ones; finally, it takes longer and is more inconvenient on account of having to make the spinal injections oneself and to await the results than to hand over to an assistant the complete care of the anæsthetic. Moreover, the attempts which have been made are not encouraging. Against one success recorded by Leriche in the case of a simple wound in the stomach we must reckon two deaths before the operation could even be begun, observed by Cotte and Latarjet, and other failures necessitating the use of chloroform noticed by Rouvillois as well as by myself.

Briefly, spinal anæsthesia seems best rejected.

There remains general anæsthesia. But should this be by ether or chloroform? Ombrédanne's apparatus gives such absolute safety in the employment of ETHER by controlling the absorption and diminishing the quantity absorbed, that many surgeons employ it regularly in the visceral surgery of the abdomen; they have not noticed that it causes any more thoracic complications than does chloroform. But here the conditions are not normal; the patients are already cold, perhaps already suffering from unrecognised or neglected affections of the thorax; the operating stations and hospitals have varying and inconstant temperatures. Ether finds out all these disadvantages. Finally Ombrédanne's apparatus does not form part of the ordinary outfit, and, if it has been supplied to

certain privileged units, the greater part have had no share in this liberality !

Here, then, is the result of an examination of facts. Schwartz and Mocquot gave up ether to return to chloroform. Stern, a partisan of ether, noted a death from pneumonia after three days, and this was from a simple penetrative wound ; it is probable that the anæsthetic was responsible for this accident. In another case one of Gatelier's patients died of pneumonia on the thirty-first day (this, it is true, was a thoraco-abdominal wound).

In order, therefore, to avoid thoracic complications, Gatelier and his collaborators rub the chest with alcohol after the operation, and make the patient breathe through a compress during the hours which follow. For this purpose they have arranged at one end of their huts a sort of post-operation room separated by a half-partition with cloths stretched over it ; the rest of the ward is heated to excess " with a Gadin stove on which is placed a saucepan of boiling water to prevent the air becoming too dry." Do you think that such complicated installations and attention are compatible with the pressure of work, and all the emergencies that face the army surgeons ?

It is for exactly this reason that we prefer the use of **Chloroform.** For our own part, we have never noticed the frequent syncopes nor the jaundice of which Gatelier speaks. Generally speaking, all war-patients (except certain alcoholic subjects) yield quickly and quietly to the anæsthetic if it is given slowly at first.

In practice we begin administering the anæsthetic as soon as the painting with iodine is finished, and the interfemoral V-support is adjusted, in order that the patient may not have to be moved again. The arrangement of the instruments, forceps, clamps, etc., for operation, and the simple inspection of the wounds fill in the time while the patient is being anæsthetised ; it is advisable for anæsthesia to be complete before any

operative act is begun, otherwise the patient is sensitive, moves, and struggles; the anæsthetist increases the dose; no time has been gained, and the patient absorbs in the end a larger quantity of chloroform.

Stern advises interrupted anæsthesia in order that the control of the intestinal mass may be aided by the pressure of abdominal resistance and also because movements of the intestines are not very painful.

We think that it is an advantage to work as quickly as possible, and, thanks to a complete and steady anæsthesia, this can be done. At the same time it is so exceptional to be able to treat visceral hernia before having made a survey of the deep-seated injuries, that to begin with that before anæsthesia is established seems to us an inadvisable practice with very rare exceptions.

It is obvious that steady and complete anæsthesia does not mean "chloroform by the pint," but that, on the contrary, the patients ought to take as little chloroform as possible.

The Operation

Preliminary exploration of the openings.—This is always essential when there is but one orifice. It ought then to consist in freely opening, verification of the penetration, and treatment of the lips of the wound by scraping the contused tissues, and freshening of the skin. In doubtful cases it is this exploration alone which enables one either to make sure of the penetrating nature of the wound, or helps one to decide that laparotomy would be useless, or at any rate should be limited to a purely exploratory incision.

Here is an example:

M——, wounded June 7th, 1915, was injured by a shell-splinter below and within the right anterior-superior iliac spine. There was an orifice the size of one's thumb leading under the crural arch. The abdo-

minal pains localised in the right side were accompanied by a very strong parietal resistance in the iliac fossa. T. 39·6° (102·2° Fahr.), P. 378 *Sub-peritoneal laparotomy* led to the peritoneum ; we were still uncertain ; an incision was made in the peritoneum ; there was no hæmorrhage, the general appearance was normal. We immediately stitched up at two levels. Free opening up of the track and sub-peritoneal drainage was set up. Recovery. (Abadie [31], Obs. 1).

The direction of the course of the projectile verified by the finger may give useful help for further examination of the injuries; pieces of clothing embedded in the walls had better be removed, and the bruised tissues dressed ; in short, the wound will have already received surgical treatment, whether it is to be included in the coming incision or is to become an opening for drainage.

Exploration also is necessary in the case of two openings near together, especially in the flanks. It enables us to perceive that a penetrating wound may remain extra-peritoneal, and will enable us to decide on a sub-peritoneal laparotomy or even on a simple external incision. Because we failed to do this, we had one fatal case which the more prudent method would have saved.

This case deserves to be reported on account of the lessons it contains.

H—— was wounded May 19th, 1916, by a rifle-bullet which went into the right flank 5 cm. under the end of the tenth rib on the mid-axillary line, and came out just by the posterior middle line between the third and fourth lumbars. Abdominal resistance slight and confined to the right flank, One attack of vomiting. Urine clear. T. 39° (102·2° Fahr.), P. 334 Twelve hours afterwards a *lateral laparotomy* outside the external edge of the rectus muscle showed the abdominal cavity to be intact ; but the mesocolon was raised by a large suffusion of blood. By a longitudinal

incision detaching the colon we discovered *two lateral perforations of the colon connected with each other*, whence issued only a mixture of blood and intestinal contents. I protected the wound with swabs soaked in ether. I closed up the two perforations with difficulty by sutures on two different planes, besides the general suturing: at this level there was no peritoneum. The whole area was washed out with ether, the lateral detachment fixed in place, and tube for drainage placed in position. Suturing was on one plane.

The patient died May 23rd. The *autopsy* showed that the mesocolon contained some very fœtid pus (cellulitis) and circumscribed peritonitis, but with fœtid fluid in the recto-vesical pouch.

Conclusions.—1st, that we ought to have laid open the wound, and, seeing that the lesion was extra-peritoneal, we should not have performed laparotomy, unless the operation had been subperitoneal, and by the gaping wound might have established a fæcal fistula; 2nd, the recto-vesical pouch ought to have been drained; 3rd, the infection of the mesocolon is an example of retroperitoneal cellulitis on which Wallace laid stress (see p. 372).

Preliminary treatment of visceral hernias.—As a rule, it is best only to clean them, wash them in hot serum, mark the already existing injuries, and cover them with hot compresses; the lips of the wound can be attended to afterwards. But *we must wait for a complete examination and verification of the intra-abdominal injuries before suturing, resecting, etc.*, th intestinal loops which have come out of the abdomen. If we neglect such an examination we risk wasting time on unnecessary local work; for instance, a loop of the intestine carefully made good may have to be removed again because there are lesions in its neighbourhood which may affect it. It would be better to isolate it carefully with warm saline swabs and then carry out laparotomy at once.

In certain cases, hernia of the viscera can be treated at once.

The omentum may be exposed by itself; we can resect, and if the incision for laparotomy does not pass through the actual opening, the stump of omentum can presently be drawn out of the abdomen itself.

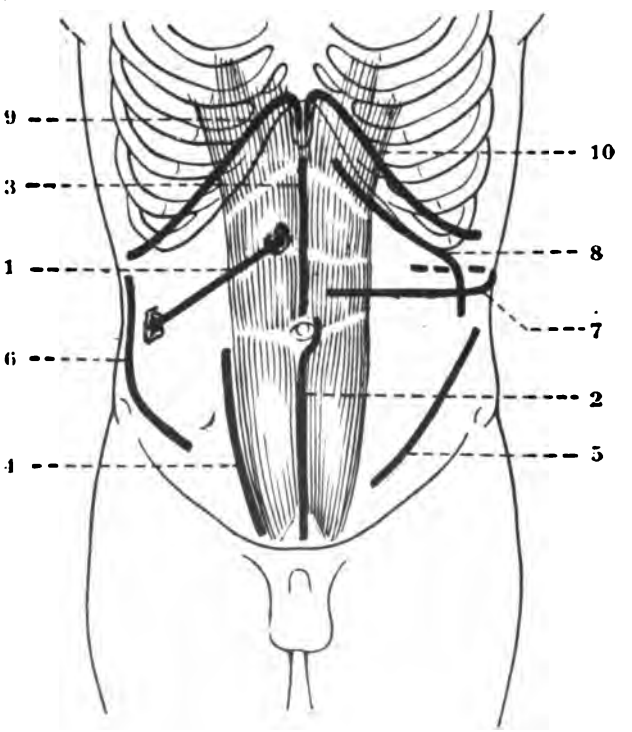


FIG. 52.—The various incisions for laparotomy. (1) Transverse incision from orifice to orifice; (2) sub-umbilical median laparotomy; (3) supra-umbilical median laparotomy; (4) lateral laparotomy, outside the rectus; (5) oblique iliac laparotomy; (6) lateral laparotomy (extreme); (7) horizontal laparotomy; (8) sub-costal laparotomy; (9 and 10) incisions for a mobile costal flap. (Auvray-Baudet.)

We pursue the same course when a parietal opening has tangentially abraded the tissues and the peritoneum, allowing the loops of the intestine to protrude whether they are injured or not; if one is sure that

there are no other intra-abdominal injuries they can be repaired at once. Under other circumstances it is better to verify the extent and position of such injuries in the preliminary investigation.

If there is persistent hæmorrhage it may be important to stop this at once ; in our own case (p. 517) we thus removed the ruptured kidney, which was bleeding profusely, before repairing the colon, which presented at the wound.

The *incision* (Fig. 52).—If we know the probable position of the greater part of the lesions—that is to say, if the two openings determine the course of the projectile—the incision ought to lead towards these lesions in the most convenient way. Thus, if the track is transverse or oblique the incision may with advantage divide the parietal wall between the two orifices, because the lesions are thus exposed. If the track is clearly antero-posterior the incision will be vertical and will pass through the anterior opening ; and we shall come down on to the injuries arranged one above the other from front to back. If the passage is somewhat oblique, it might be more advantageous to leave the orifice out of the question in making the incision and to make a median or lateral laparotomy in such a manner as to bring the exploratory incision towards the plane of the posterior orifice of exit.

If we do not know the position of the injuries—that is to say, if there is but one orifice—we must choose an incision which gives the best opportunities for exploration. This will be, *as a rule, supra- and sub-umbilical median laparotomy* and without regard to the orifice.

In certain cases of lumbar wounds or wounds of the flanks or of the epigastric region it may be convenient to make a *horizontal* or *transverse laparotomy*. But, with the exception of these special cases, this incision gives a smaller area for exploration than the median vertical, even with Mayo's pad.

Here, for instance, it allowed us to repair not only a perforation of the ascending colon, but also to treat a suppurating appendix at the same time.

L——, wounded March 31st, 1916, had a penetrating wound in the right flank; abdomen painful on the right side; T. 38·2° (100·7° Fahr.), P. 386 By means of *horizontal laparotomy* I found an *intra-peritoneal perforation of the lower third of the ascending colon;* sutures in two stages. But *liquid pus* flowed spontaneously from the region of the cæcum and I exposed a large, turgid appendix, bathed in pus, surrounded by a zone of inflamed loops of the small intestine; excision of the appendix; two large drainage-tubes. "Drop by drop." Patient placed in the right lateral decubitus. Recovery.

In order to examine lateral wounds more easily, we must not hesitate to add to the incision already made (vertical, for example) another one either horizontal or oblique parallel to the edge of the false ribs.

We shall see later on what particular type of incision is best for the exposure of the liver or of the upper part of the stomach or of the spleen.

As a general rule, the laparotomy ought to be extensive and give complete opportunity for exploration; the median sub-umbilical incision ought generally to be immediately prolonged above the umbilicus. And as soon as the abdomen has been opened up as far as the pubis it is advisable *to place the supra-pubic valve in position*, as this gives fuller exposure and avoids having to make inconvenient manœuvres.

Detection of the principal focus of the lesions —As a rule, the abdomen is copiously filled with blood or with blood and intestinal contents. Without handling the viscera as yet, we must soak up the blood with swabs. The character of the effusion gives us at once some useful hints.

If very copious and dark the blood probably comes from the liver or the spleen; if of a brighter colour it

comes from the mesentery or the posterior abdominal wall, and one often sees also hæmatomata of blood pushing up or separating the substance of the mesentery or the meso-colon. When blood is mingled with intestinal fluids it indicates an injury to the small intestine. And this is certainly the case if one should find worms in it, as I once did myself!

Half-digested food and odourless gases suggest a perforation of the stomach.

Fæcal matter and a fæcal odour are signs of injury to the large intestine.

Pus is the proof that peritonitis has already set in; we detected its presence less than twelve hours after a wound in the buttock!

But here is the most familiar picture: distended loops of the small intestine are collected in congested masses; some are even showing perforations or lacerations. On the other hand, the rest of the small intestine is composed of loops in a normal condition, with irregular contractions, of a pale colour—"dogs' intestines." *The lesions are in the distended loops*, and one should begin by attending to these.

Treatment of the Lesions

(*a*) **The Small Intestine.**—Before treating the lacerations or perforations individually, we must make an inspection of the whole of the suspected part, and of all the distended loops. We mark off in some degree the injured points by pressure forceps which ensure coprostasis; we clean them up at the same time and isolate them under hot saline swabs; one sees at once which perforations ought to be sutured separately, and which require removal of a portion of the intestine.

A simple punctiform perforation is closed with a purse-string stitch. A more extensive perforation with irregular edges will be freshened by a cut in the shape of a lozenge with two snips of the scissors and sutured in two stages transversely.

A longitudinal wound may necessitate resection of a wedge-shaped piece of intestine ending at the edge of the mesentery, with end-to-end anastomosis.

Complete sections of the intestine perpendicular to the axis will be sutured end to end, after putting the cut ends in order, if necessary. In certain cases everything is cut except the musculo-serous membrane over a certain area; this "bridge" will be left untouched, and by a complete circular suturing the repair of the sero-serous membrane will be completed.

Resection is clearly necessary for a segment of the intestine cut longitudinally for a considerable extent (explosion) or ruptured and torn away from the mesentery.

There are also cases in which we must deliberately remove quite a long segment; many perforations succeed each other without leaving enough tissue between them to allow of the stitches being sufficiently deep to make a firm suture, or perhaps the tissues appear to be badly injured; the perforations are numerous and their individual reparation would take too long; there may be also holes in the mesentery or rents at its point of insertion. (See Figs. 9 and 10.)

There must be no hesitation; the corresponding segments of the intestine are liable or even doomed to secondary necrosis; resection is absolutely necessary.

But here is a contingency which is open to discussion. The lesions are grouped in such a manner as to necessitate a preliminary resection of from 10 to 30 cm., there follows a second resection, and, between the two, there will remain a piece of sound intestine from 30 to 50 or even 75 cm. long. Will it be better to make each excision separately, leaving the intermediate piece of sound intestine intact or to take out the whole segment and thus make only one extensive resection? One of our cases which we will report is rather in favour of the second decision.

G——, on May 2nd, 1916, was injured by multiple fragments from a grenade of which one entered halfway up the rectus muscle; a small opening, hernia of the omentum and no visible exit. The abdomen painful; neither flatus nor stools; urine clear. Pallor, shock. T. 38·90° (102·0° Fahr.), P. 398 feeble; 1,000 grams of saline with adrenalin.

Operation (twelfth hour).—A median sub-umbilical laparotomy which by a transverse incision was joined to the aperture where the splinter entered; resection of the surrounding muscular tissue, excision of part of the omentum. Blood, red and copious; the pelvis was filled with it. In the area underneath the parietal opening the distended and crimson loops of the intestine contrasted vividly with the rest of the intestine which was normal and contracted. We contented ourselves with drawing these loops outside and found that they showed the following lesions: (*a*) *two small connected perforations* of which one was at the level of the mesenteric insertion (closed with purse-string stitch); (*b*) *two perforations* of which one was the size of a pea (one of them closed with purse-string stitch, the other with two rows of stitches); (*c*) *four perforations* close together with jagged edges on a morbid-looking loop (excision of 5 cm., end-to-end anastomosis); at this level two or three loops of the small intestine were stuck together and we found two projectiles (Fig. 53), half buried in the intestine, with débris of clothing; (*d*) at about 30 cm. from here a *complete section* with clean-cut edges; end-to-end suture after it has been straightened up; (*e*) *two small perforations of the mesentery*. No evisceration necessary here. Ether; pelvic drainage. Suture with a bronze wire in one stage, incomplete on account of the traumatic section and suspected infection of the

FIG. 53. — Grenade fragments taken from G——, p. 495

rectus muscle. In addition laying open of numerous wounds of both lower limbs, a penetrating wound in the left sub-pectoral region, with hæmatoma; the removal of a small splinter fixed in the right edge of the sternum. Finally injections of Leclainche and Vallée's serum. The *after-effects* were exceedingly interesting. Two days later *gas gangrene in the recti muscles* (in spite, let us note, of the preventive injection of Leclainche and Vallée's serum); we took out all the metal sutures; the omentum, which had been carefully spread out, appeared normal and covered up the intestinal mass. Dressing with ether.

On May 6th a natural stool, and from that time onwards there was normal progress as far as the intestines were concerned. The abdominal wound was gaping widely; after treating with hot air and heliotherapy we were able little by little to bring the lips of the wound together by means of lateral strips of adhesive plaster with hook-attachments; the edges were brought together by a catgut lace.

After a period of profuse diarrhœa with rapidly increasing exhaustion, assimilation improved and his food was increased by degrees.

Meanwhile general bilateral bronchitis set in. On May 31st the patient was evacuated to Paris (Panthéon Hospital, under Leriche).

During the whole of June he got rapidly better; the extraction of the numerous splinters still embedded in the wound caused the suppurations spread all over the two lower limbs to dry up and the patient visibly put on flesh.

Quite suddenly at the end of June *intestinal obstruction* declared itself, and seemed to be about to prove fatal. But suddenly an intestinal fistula appeared, half-way between the pubis and the umbilicus, and an abundant evacuation of fœtid intestinal contents greatly improved the situation. On July 5th, in passing through Paris, I myself examined the patient;

the night before they had extracted by means of the fistular opening a scrap of dead tissue containing a thread of silk (?) and I myself removed a portion of dead intestine 25 cm. long with a corresponding piece of mesentery. Another abundant stool followed the removal of this foreign body which formed an artificial stoppage; the condition of the patient improved; the temperature fell to 38° (100·4° Fahr.), P. 386, and hope was renewed.

But the fistula was high up; particles of food passed without being digested; and weakness became more and more marked. Death came on July 16th, *two months and a half after the wound.*

How can we explain this case? Clinically and anatomically the sloughing of this long segment of intestine can only be explained by septic arterial thrombosis, the segment affected was probably that which separated the resection and the complete section. It would not perhaps have occurred if the whole segment had been taken away by resection, the whole extent of which was not sufficiently large to be by itself a new and serious factor.

It appears to us, therefore, that in similar cases, especially if the injuries to the mesentery, which even though small are always septic, can affect the blood supply, it would be best to excise the intermediate section.

Some surgeons have tried to obliterate confluent or extended perforations by joining up a neighbouring loop (Stern), but these attempts never gave good results. They are best left alone. In all these cases, resection seems to be the safest, most rapid and least injurious method.

Only as a last extremity ought one to have recourse to *making an artificial anus* of a ruptured loop of the small intestine. For either this is the only lesion and it is inconceivable that we should not find time to attend to it, or there are many lesions of which the very

multiplicity would lead us to adopt a similar course ; it would be better then to risk a possible death under a complete operation which might even result in recovery rather than to court certain death by exhaustion.*

The method to be followed for intestinal resection.— Latero-lateral anastomosis undoubtedly takes more time ; we therefore prefer the circular, end to end. We never employ Murphy's button ; a neatly made suture in two rows is much quicker.

Here are brief details of the method which experience has shown us to be the best.

Two clamps ; section of the intestine for a length of 3 cm. on the inner side.

Section in an obtuse V of the mesentery leaving 1 cm. of mesentery projecting inside the intestinal section. The vessels are ligatured with catgut ; the threads are left hanging down, by placing them opposite each other and tying them from slit to slit ; once the intestinal suture is made, one can effect the closing of the mesenteric breach rapidly, and as a rule without overstitching. The two ends of the intestines are brought together like the barrels of a gun and kept in place by two Chaput's forceps, mesenteric edge to mesenteric edge, and free border to free border. Then we make a complete overstitching beginning in the middle of the posterior semicircle, with a loop of thread on two needles knotted. The left thread does the oversewing on the mesenteric side, turns carefully at the level of the angle, and comes to the front ; in the same way the right-hand thread makes the stitches on the free edge and is tied to the first thread, in the centre of the anterior semicircle.

* One of Tisserand's patients had eight perforations on one loop of the small intestine which was resected. The patient's condition not allowing an anastomosis, the two ends were joined to the skin. The patient recovered from the operation very well, but died on the seventh day from rapid wasting ; the excised loop was very close to the duodenum.

One may then begin the suturing of the serous surfaces, which is done from right to left, and from front to back ; one of the needles goes through the mesentery (take care not to prick the small arteries !) continuing the deep suturing, and the two threads are tied together at the back.

One more point. We never make X-shaped stitches (called *stops*), because we find them useless, and because they make the suturing less regular and less tight.

We tie together two by two the ligatures of the mesenteric sections. For *latero-lateral anastomosis* we always find it very convenient to use the double forceps (Témoin-Abadie). We have too often seen the vessels bleeding at the edges of the area flattened out by the "écraseur" to advise its being used on the intestine.

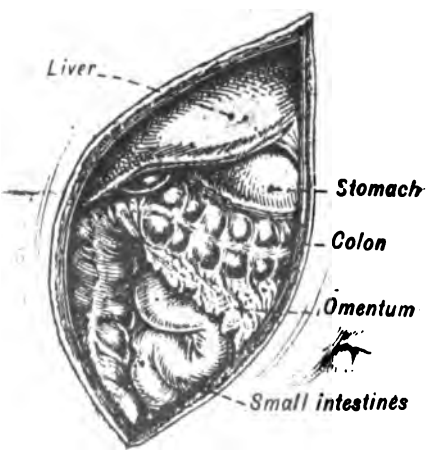


FIG. 54.—Exposure of the right angle of the colon and the neighbouring organs after Kehr's laparotomy.

After every suture the intestine is washed with ether, then placed under a swab soaked in saline until it is put back in its place.

(*b*) **The Large Intestine.**—There are two segments particularly difficult of access—the two angles, and the left even more so than the right.

The sub-hepatic angle is generally exposed during an operation which involves the liver, such as Auvray's incision prolonged vertically downwards to its outer extremity, a sub-costal incision also prolonged vertically outwards, and Kehr's extensive incision (excep-

tional) which gives a wide exposure of the whole region as shown in Fig. 54.

The *splenic angle* is most conveniently reached by a sub-costal incision with an external vertical prolongation (Fig. 55).

When the colon has a long mesentery over its whole extent or in those parts which are generally well

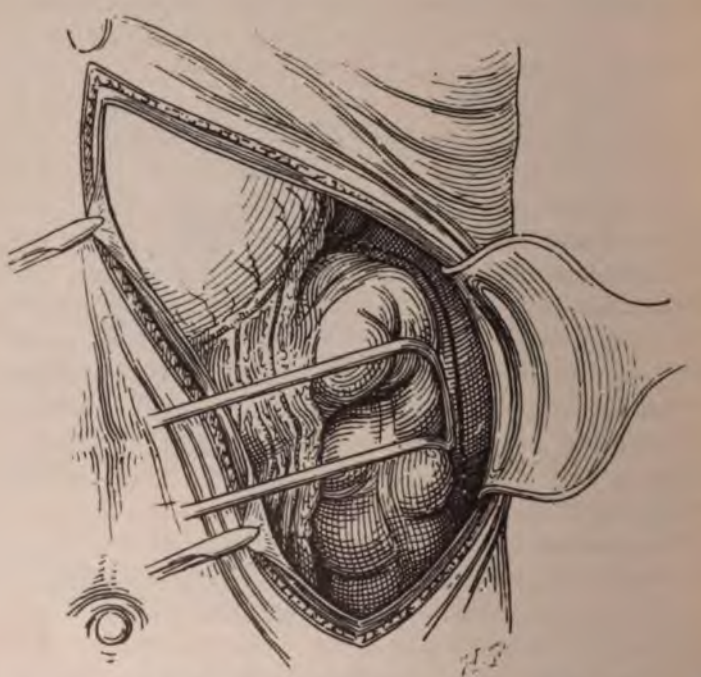


FIG. 55.—Left sub-costal laparotomy with vertical prolongation. The stomach, the upper part of the spleen, and the splenic angle of the colon are brought into view. The dotted line shows the incision for effecting the detachment of the colon. (Borrowed from Guibe.)

provided with pedicles (the transverse colon and the sigmoid flexure), the method of reparation is nearly the same as that for the small intestine. The greater extent of the insertion of the mesentery is, however, always a cause of difficulty. If the appendices epi-

ploicæ are in the way, it is no waste of time to tie them firmly at the base and remove them from the area of operation.

In the cases where the shortness of the mesentery is a source of inconvenience in preventing the organs to be examined and treated, from being easily drawn outside, we must not hesitate to make a "*lateral detachment*" by dividing the peritoneum longitudinally the whole length of the mesentery and pressing back inwards the colon and its vascular layer.

Its mobility is thus considerably increased. It does not seem advisable here to re-attach the colon to the walls by suture; it would be better to leave this coalescence to be established later, and not to run the risk of infection of the area of cleavage, which is deep and has no outlet. On the other hand, if the penetrating wound is posterior and leads, after being freely laid open, to the focus of the lesions and allows of easy communication and good posterior drainage we may find it very advantageous to suture the external parietal edge of the cut peritoneum, to the anterior surface of the colon; in this way the whole external posterior surface of the colon is exposed and separated from the peritoneal cavity. Infection of the area or a fistula would not in this case be very serious. We owe a recent success to this method.

End-to-end anastomoses of the colon are always difficult, especially when it is sessile on account of the length of the suture where the enclosed portion is not in the serous layer. When possible it is best to begin in these cases by a strong posterior back-to-back suture before doing the complete circular overstitching. But this operation is always delicate and uncertain and much more tiresome because we have to use curved needles, and the surrounding tissues are soaked in blood. If by good luck we have the necessary material to make two deep rows of sutures we must not hesitate to do so. A plastic of the omentum is

very useful in giving additional strength to these delicate sutures. Yet in spite of all our care a fæcal fistula very often supervenes, but this is not really alarming, for as a rule it will gradually disappear of its own accord.

The uncertainty of the sutures and the frequency of fistula are reasons which make us prefer to treat the

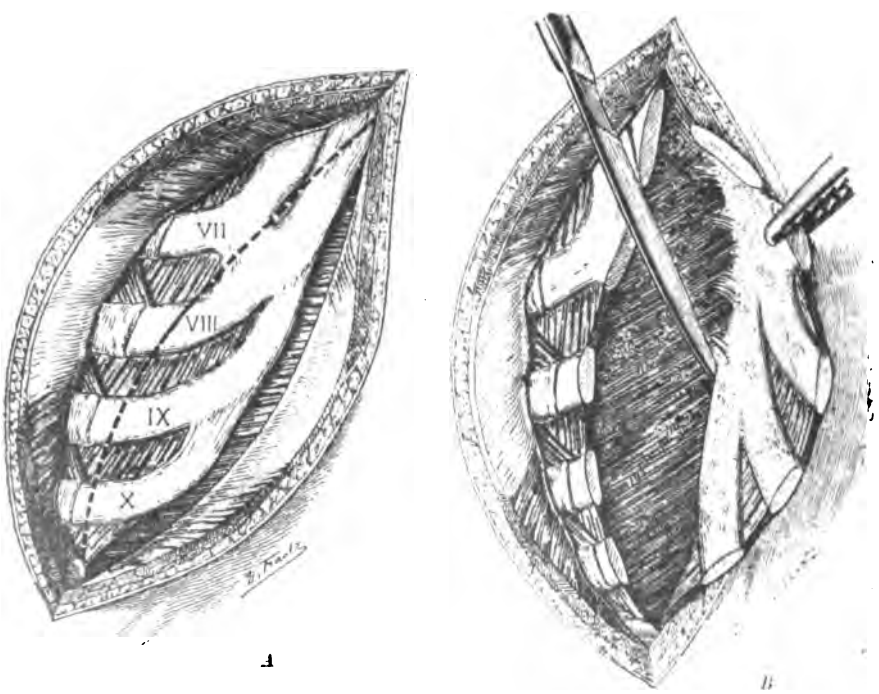


FIG. 56.—Auvray's method for reaching the upper surface of the liver (Guibe). (*A*) Parietal incision; the dotted curve shows the line of section of the costal cartilages; (*B*) the scalpel applied closely to the deep surface of the cartilaginous flap to avoid the pleura and detach the diaphragm.

large intestine *by exposing it and making the artificial anus*, which we have condemned as regards the small intestine. Such results as have been published are, as a rule, highly unsatisfactory. But the high mortality is due to the fact that this expedient is only resorted

to when every moment gained is very valuable, that is to say when the general condition of the patient is very serious. What we have to remember is that, as Quénu advises, we should make the special lumbar incision, through which the loop to be exposed will

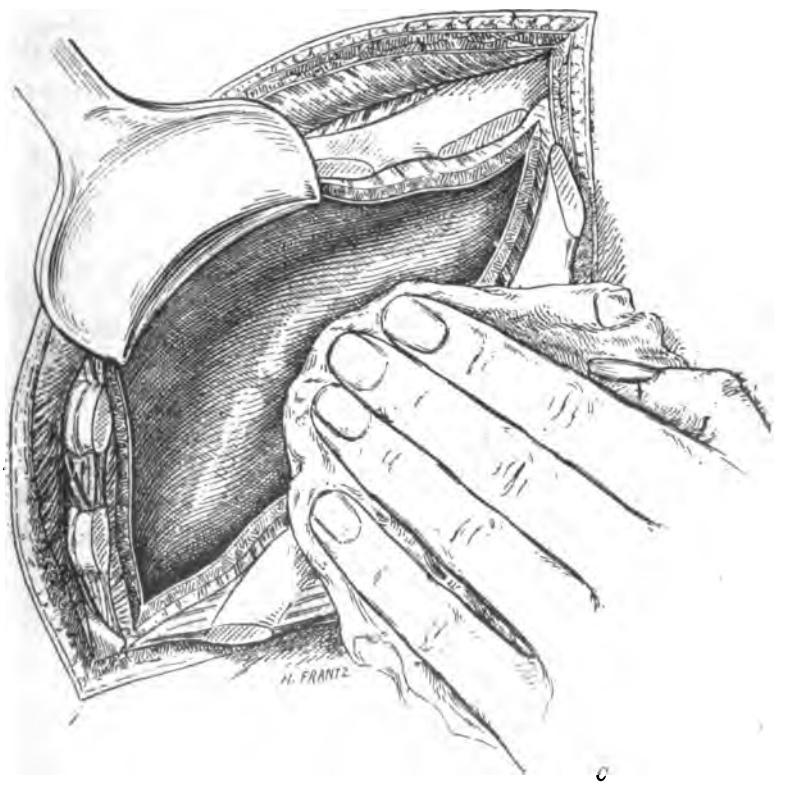


FIG. 56.—(*C*) The diaphragm being incised as well as the peritoneum, the hand hooks up the liver to permit access to its upper surface.

pass, as far back as possible. The preliminary detachment of the mesentery might be advantageous.

In a case of urgency we might equally well have recourse to the following procedure: resection of a segment of the colon, closing up and enclosure of the distal

end, and opening of the cæcal end at the skin (Bouvier and Caudrelier, two cases, two deaths). Unilateral exclusion of this kind and the entero-anastomoses which accompany them are only to be resorted to under exceptional circumstances.

(*c*) **Liver.**—Easy access to the dome of the liver is obtained by Auvray's method, of which we will give a brief description (Fig. 56). An incision leading from the xiphoid cartilage to the tip of the eleventh rib passing by a finger's breadth above the costal margin ; laying bare of the costal cartilages, incision by the bistoury, beginning at the xiphoid, dividing the eighth cartilage on the inner side, separating it from the seventh, then making a fresh incision on the inner side of the chondro-costal articulation, finally dividing the ninth and tenth cartilages ; we keep close to the deeper surface to make quite sure of avoiding the pleura ; the diaphragm and the transverse colon are detached, and the peritoneum opened.

In the case we are considering, this line of access is generally used to complete a median supra-umbilical laparotomy, or else an incision going from one orifice to the other.

The following case is an example :—

B——, on June 19th, 1915, was struck by a bullet which caused a large tunnel-wound near the false ribs on the right side with diffuse hæmatoma, hernia of the transverse colon and of a loop of the small intestine, extrusion of the omentum and hepatic hæmorrhage. The patient lost a lot of blood and was very pale. He was operated on ten hours afterwards. *The tunnel was converted into a trench* ; the abdominal cavity was thus opened extensively ; *resection of the costal cartilages* exposed the dome of the liver ; we pressed back the transverse colon, the omentum, the small intestine and then the liver, and found a deep lacera tion 4 cm. long. Suture, by means of U-stitches in coarse catgut ; drain ; restoration of the walls stage

by stage. Recovery, but not without abundant localised suppuration. (Abadie [33] obs. 7.)

The lower half of the liver is easily accessible by means of the transverse incision.

How shall we treat the actual lesion ? As a rule, small wounds in the liver cease to bleed of their own accord ; we had better do nothing but compress them gently with gauze swabs.

Deep tunnels should be drained, the drain being well packed round with gauze.

Wide openings are sometimes successfully brought together by U-stitches in thick catgut facing each other, but not crossing; but, however paradoxical it may seem, we believe that if we can stop the hæmorrhage by plugging, this method is preferable to suture. We must not forget that the edges of the openings are irregular, contused, and often infected ; the septic areas will be cut off, and enclosed between the threads. It would be better to have a large gaping opening.

In cases of severe hæmorrhage, we can, as easily, *interpose as a plug a piece of the omentum* over which the edges of the liver are fastened. A drain must be placed below that part of the hepatic zone where the wound is.

Often there will be no other resource but that of very tight plugging with pieces of gauze quickly but evenly packed in.

It is better to remove a *torn gall-bladder* than to suture it ; or the opening may be tightly enclosed by a large drain opening to the exterior.

(*d*) **The Stomach.**—The wounds on the anterior surface are easily discovered, the edges trimmed and sutured.

We should always carefully attend to hæmostasis of the peri-arterial circle. Two of the gastric zones require special means of access, first of all for the inspection and then for the repair of the injuries. These are the higher part under the diaphragm, and the posterior surface.

The treatise by Forgue and Jeanbrau * is the best to study on this question.

The *upper part of the stomach* is most easily reached by a similar incision and a similar method on the left to those which have been described for the liver on the right. Baudet recommends the following procedure: division of the seventh costal cartilage near the sternum, section of the eighth and seventh ribs in the nipple line; one thus obtains a kind of movable flap, which can

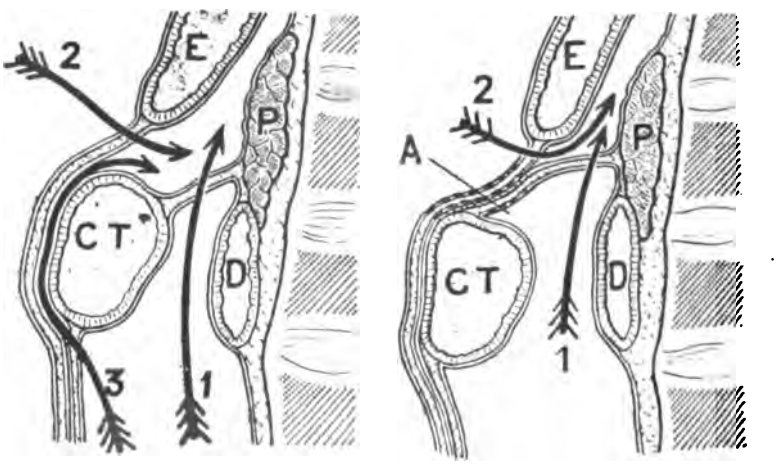


FIG. 57.—Section, vertical and sagittal, to show the routes to the lesser sac of the peritoneum and the posterior surface of the stomach: (I. 1) Trans-mesocolic route; (2) inter-gastrocolic route; (3) Inter-colo-omental route. (II) Anatomical arrangement of the parts which renders impracticable the inter-colo-omental route by reason of the extensive and fenestrated adhesions of the omentum and the mesocolon (A).

be lifted up to allow a view of the spleen, the left lobe of the liver, and the upper part of the stomach (Fig. 63).†

* Forgue and Jeanbrau, "Gunshot Wounds of the Stomach" *Rev. de Chir.* Sept. Oct. Nov. 1903.

† In spite of the fact that text-book descriptions represent the pleural cavity as being slightly higher on the left side, nevertheless the greatest care must be taken in dividing the cartilages and in uncovering the flaps from behind, for one may find abnormalities; in the patient whose case we have represented on Plate IV the pleura is within a finger's breadth of the edge of the thorax.

A valve or a powerful retractor will raise the costal framework. This line of approach gives an extensive exposure of the stomach and spleen.

The posterior surface of the stomach should be syste-

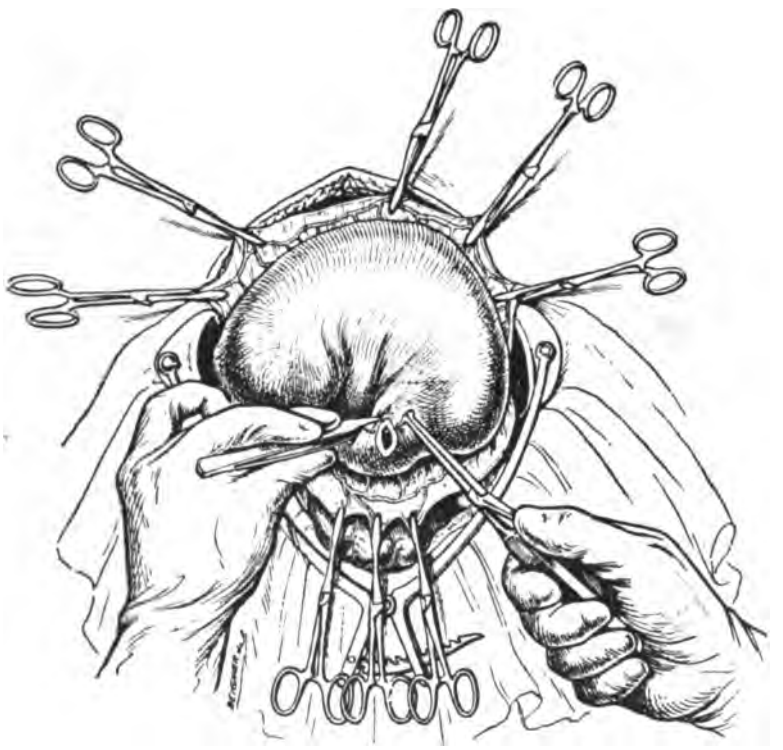


FIG. 58.—Gastro-colic means of approach, through the omentum, to the posterior surface of the stomach. After section of the omentum, the two edges of the wound which are marked by the forceps which are effecting haemostasis, the stomach is tilted from below upwards. A perforation, even if quite high up, is thus readily sutured (after Forgue and Jeanbrau).

matically examined even when only a single perforation has been found on the anterior surface.

These methods of procedure now bring us quickly to the lesser cavity of the peritoneum, that is to say to the posterior surface of the stomach (Fig. 57 and Plates II and III).

The first consists in making an opening through the *transverse mesocolon* as in gastro-enterotomy.

In one instance where laparotomy allowed us to suture a small perforation of the stomach in front of and above the greater curvature (F——, March 17th,

FIG. 59.—Access to the posterior surface of the stomach by the inter-colo-omental route. "The abdomen is open, the Gosset retractor keeps the walls apart; the scalpel is seen with its point scratching the transverse colon at the insertion of the great omentum" (Pauchet [73]).

1916), it was necessary to examine the posterior surface: an opening rapidly made through the transverse

PLATE II

FIG. C.

FIG. D.—A. r. Renal artery. F. Fragment detached by explosion.

FIG. E.

Explosive lesions of the liver, *produced by bullets* (Fig. C–Vp, Portal vein. Vb, bile duct) and of the right kidney (D) with extensive laceration of the pelvis; complete section of the angle of the ascending colon; perforation of the vertebral column, with laceration of the spinal cord. Bullet entered under the right costal margin; went out in the left lumbar region. (Part of post-mortem on a wounded man brought in dead.) The following abnormalities were also found: the *descending colon*, the splenic angle of which was against the vertebral column, passed under the root of insertion of the mesentery; it emerged at the level of the ***right*** iliac fossa, and the rectum descended to the right of the sacrum. Finally, the *left kidney* was at the level of the upper outlet of the pelvis (E).

mesocolon showed that the posterior cavity of the omentum (lesser cavity of the peritoneum) was sound; the projectile had probably remained in the stomach. The abdomen was completely closed up again. The wound healed by first intention.

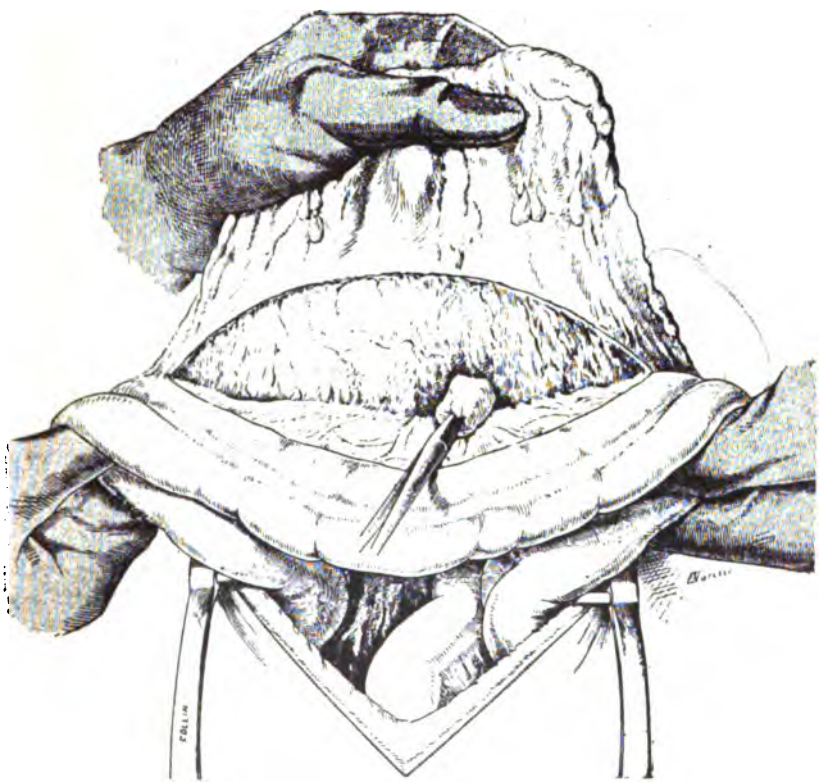


FIG. 60.—"The inter-colo-omental detachment, commenced with the scalpel, following the black line, is continued with the aid of a pair of forceps holding a gauze swab. It will be noticed that the mesocolic vessels allow themselves to be separated readily with the great omentum without hæmorrhage." (Pauchet [73].)

But, this route being narrow and long, though it would suffice once in a way for an examination, is awkward for suturing a perforation. We will, therefore, disregard it.

The second passes *through the great omentum* at the level of the greater curvature (Fig. 58 and Plate II); we divide the omentum above the arterial arch, liga-

FIG. 61.—"The great omentum, completely separated from the transverse colon, has been detached, and drawn up with the stomach. The gastric perforation will be easy to suture. The pancreas presents between the mesocolon and the stomach; the duodenum can be seen as far as the pyloric vein." (Pauchet [73].)

turing one after the other branches which descend into the omentum; this incision can be extended if neces-

PLATE III

FIG. F.—Abdominal cavity widely opened by removal of the anterior wall. The organs seen *in situ*. Note the curve of the sigmoid flexure and the extensive overlapping of the gut by the omentum.

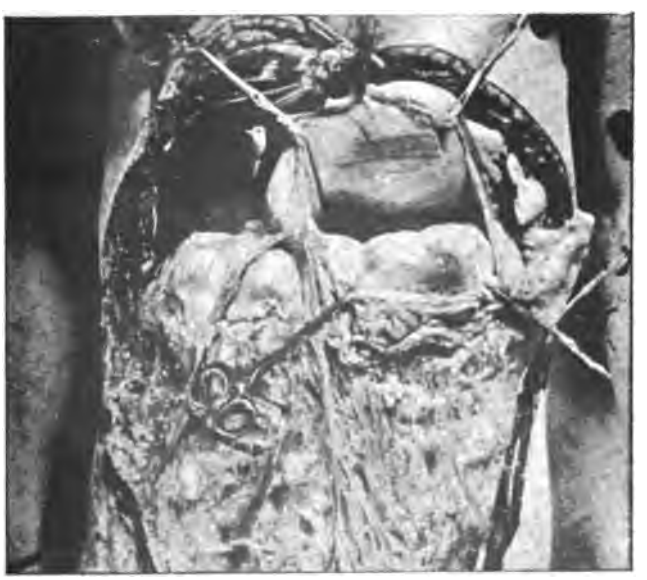


FIG. G.—Line of access between the transverse colon and stomach, across the omentum, to the posterior surface of the stomach. The omentum is divided below the perigastric arterial circle; forceps are placed on the omental arteries.

sary; the posterior cavity is now completely open; the stomach is now tipped from below upwards in order to discover the perforation and suture it. Then the opening in the omentum is sewn up. This method is inconvenient because hæmostasis is required.

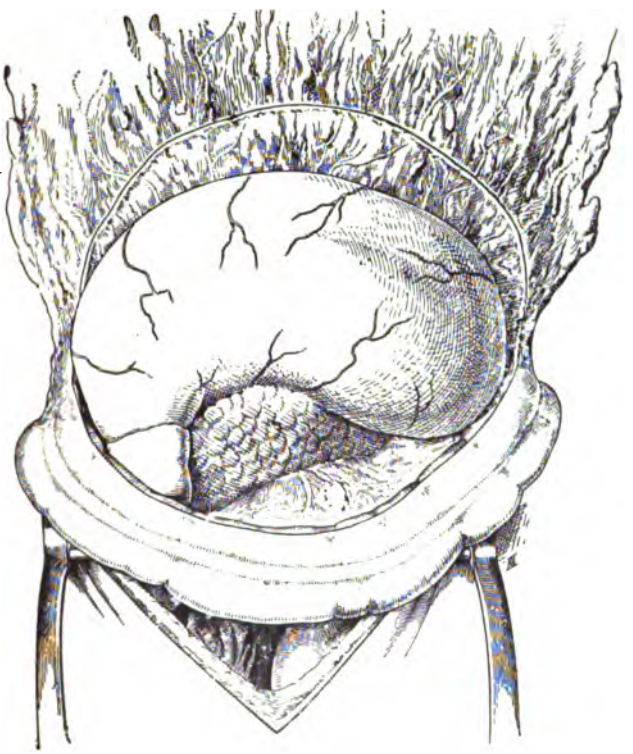


FIG. 62.—"How gastric perforation is sutured. This one has been obliterated by four separate perforating sutures; a portion of the great omentum has been placed in contact and fixed by some separate stitches. The rest of the colon is going to be placed behind the omentum. The transverse colon will be sutured directly to the greater curvature of the stomach." (Pauchet [73].)

Pauchet [73] suggests reviving the method of *detachment of the inter-colic omentum*; we reach the posterior cavity by lifting up the omentum and making an incision (splitting it) above the colon. The figures

given here and the notes under them do away with any necessity for further description (Figs. 60 to 63 and Plate III).

This method, seductive as it may be, is not always possible, and on two occasions (notably on that represented on Plate IV) we have found on the dead subject, between the stomach and the colon, an omentum already penetrated because the coalescence of the constituent layers, instead of being arrested only below the anterior edge of the transverse colon, went up much higher, almost to the edge of the stomach.

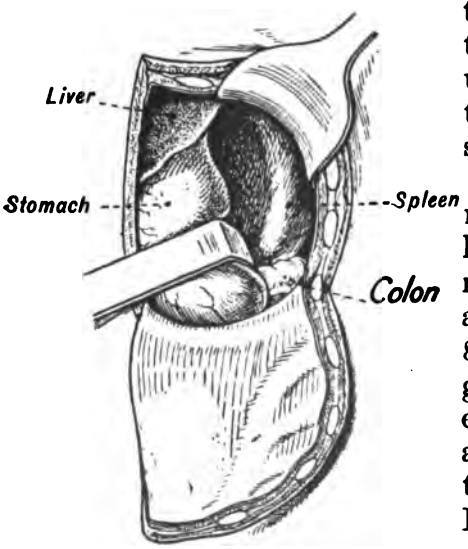


FIG. 63.—Access to the left edge of the stomach, the spleen, and the splenic angle of the colon after laparotomy with the resection of a cartilaginous flap in the thorax.

However, this arrangement is not unknown, and we find a mention of it in Testut and Jacob, vol. ii., p. 84, as well as the dangers to which we are exposed in attempting an opening of the posterior cavity (Fig. 57, Plate II).

(*e*) **The Spleen.** — If we are dealing with the spleen alone, and if we have not to examine the whole of the left hypochondrium, we may make either a sub-costal or directly horizontal incision. But this is an exceptional case; generally the spleen is involved in lesions of the left hypochondrium, which therefore we must examine carefully, or it may be injured by a thoraco-abdominal wound.

In the first case we get access to the spleen by the same means as we have just used for the upper part

PLATE IV

FIG. H.—Abdominal cavity as in Fig. F, after raising the omentum and the transverse colon.

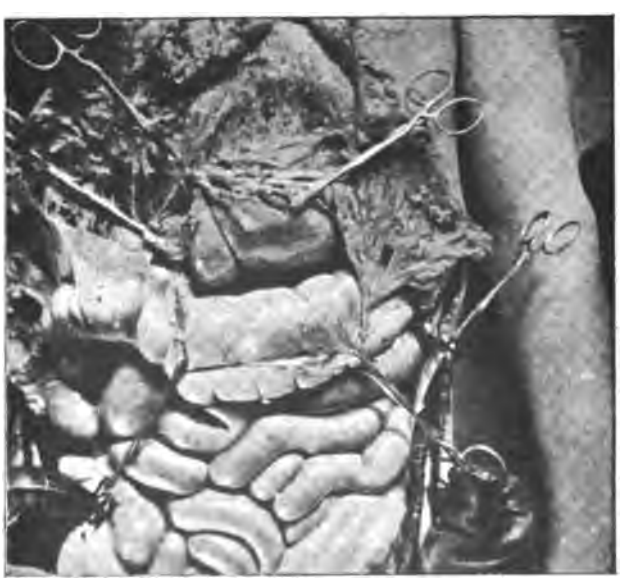


FIG. I.—Line of access between the omentum and colon, by section and detachment of the omentum and the transverse colon.

of the stomach (Fig. 63), but in order to examine the spleen properly we must prolong the incision backwards in a horizontal direction and even vertically towards the iliac crest.

The existence of a thoraco-abdominal wound may lead to two different methods of action which Delore and Kocher [76] have very clearly compared. They distinguish two clinical types: the respiratory, and the abdominal, each of which has its own preferable line of access; the diaphragmatic route in the first case, the abdominal route in the other.

They say that the diaphragmatic route will have manifest advantages whenever the blood coming from the spleen has flowed copiously into the pleura, whilst the peritoneum has received scarcely any (don't forget a rectal examination!). But if there is no blood, or only a little, in the pleura the abdominal route is to be chosen (a sub-costal incision enlarged, by means of the resection of two or three of the left costal cartilages). It has the advantage of limiting manipulations of the pleura, which is always more liable to infection than is the peritoneum.

The following is a short account of three cases, which may be said to indicate the various therapeutic methods.

First Case.—Thoraco-abdominal wound with injury to the spleen. No operation took place and at the end of two months and a half the patient succumbed to diffuse suppuration, and chronic peritonitis, in spite of many incisions to drain off the constantly collecting pus in the regions of the spleen, pelvis, left iliac fossa, etc.

Second Case.—A small wound 3 or 4 cm. long underneath the angle of the left scapula; more abdominal than thoracic symptoms. (*a*) Resection of the eighth rib, which was fractured; no blood in the pleura; wound closed (afterwards it was necessary to remove 100 grammes of serous liquid by puncture); (*b*) left

sub-costal laparotomy prolonged by a vertical incision to the iliac crest ; splenectomy. Recovery.

Third Case.—Penetrating wound of left axilla at the level of the ninth rib. An oblique incision on to the rib and resection ; a great deal of blood in the pleura ; a hole as big as the thumb in the diaphragm led to a wound in the spleen ; *the whole rib was excised and the orifice in the diaphragm was enlarged*, and by means of this, *splenectomy* was performed. The opening was closed by suturing the upper edge of the diaphragmatic wound to the thoracic pleura and thus the pleural cavity was closed (small drain) ; at the same time the lung was secured in the costal diaphragmatic sinus by two catgut stitches ; then the diaphragm and finally the peritoneum were closed. Recovery.

Plugging the spleen for a bleeding wound is generally deceptive, and it would be better to take away the organ altogether.

Considered as abnormally serious and constantly fatal in military surgery in consequence of some observations by Willems [23], *splenectomy* deserves that we should challenge such a condemnation. The two successes of Delore which we have just described in detail, one by Lammory, quoted by Quénu, another by Barbet and Bouvet, and four published by Depage [41], show that the after-effects of splenectomy are serious in proportion as the already existing hæmorrhage and the injuries of the other organs have threatened the patient's life ; 12 cases operated on by Depage or his collaborators resulted in 4 recoveries, and in 4 cases where the spleen alone was involved there were 3 recoveries.

The method for excision of the spleen has nothing very special about it, and can be summed up as follows : draw it outside by detaching the mesentery, place two firm clamps in position, cut, and above all ligature the pedicle very carefully.

In all the operations on the hypochondria and the

epigastric region, we should remember the comfort given by *Mayo Robson's cushion*, in making the deep-seated organs more prominent and more easily accessible.

(*f*) **The Kidney.**—The kidney can be reached by a trans-peritoneal route in the course of either an anterior laparotomy or of a lateral or transverse lumbar laparotomy (see following case). Plugging ought only to be used for small wounds with slight hæmorrhage. Otherwise we must have recourse to *nephrectomy.*

The technique should be simple and rapid ; the same remarks apply here as those we have made on the subject of the spleen. If combined with the treatment ot other injuries of the abdominal viscera, nephrectomy is always serious. Recoveries are unusual ; we have, however, seen one.

J——, wounded April 29th, 1916, by a bullet which entered just to the left of the umbilicus and came out in the left lumbar region with hernia of the omentum and of the descending colon. General appearance of hæmorrhage. T. 38·4 (100·4° Fahr.), P. 106. At the eighth hour direct horizontal laparotomy. Excision of the omentum ; we staunched the blood, which flowed copiously from the region of the kidneys ; we made a large opening in the peritoneum and examined the bleeding kidney ; it was ruptured and brittle (Figs. 16 and 17) ; two clamps were placed on the pedicle, *nephrectomy* ; afterwards the *descending colon was found to have been divided transversely* ; end-to-end anastomosis after cleaning up the cut ends. Drainage. Suture in one layer. On May 2nd a bronze-coloured infiltration was found in the flank ; all the stitches were taken out ; the lips of the wound were gangrenous, with a fœtid odour, and there was gas ; all the gangrenous tissue was removed, and ether dressings applied.

After this operation some amount of sloughy tissue was eliminated, but the general condition of the patient was excellent and the wound healed up without fæcal fistula.

(*g*) **The Bladder.**—We have described above how the extra-peritoneal, lower part of the bladder can be conveniently reached by an opening in the perineo-sacral or gluteal region, by placing the patient in Depage's position (ventral decubitus with the legs hanging down, in the shape of an inverted V).

Examination of the bladder will be made during a laparotomy after the pelvis has been completely dried, and a large swab placed as a barrier, the patient being arranged in a slightly exaggerated Trendelenburg's position. Now we have a very anxious moment. Perforation in the folds of the peritoneum can easily be missed, we must go slowly, carefully smoothing out all the corners, while the fundus of the bladder is taken and held by large heart-shaped forceps. Perforation once detected, we must open up the perforated peritoneum more widely still in order to get at the bladder. Ought we to be contented with closing up, even on two levels, perforation of the bladder ?

Experience has shown us that we must at the same time systematically open the bladder in the hypogastric region by cystotomy, with a large drainage-tube from the upper part. A siphon with a glass tube (as in prostatectomy) will prevent the patient from being flooded with urine. If the fundus of the bladder is also injured a long drain will go from the hypogastrium to the perineum. Not until much later on, when these wounds are nearly healed, will it be necessary to tie in a catheter. The co-existence of bladder injuries, with other wounds, greatly increases the seriousness of the prognosis.

We can ignore the case of Tartois' patient who recovered ; he had only a simple sub-mucous tunnel-wound without perforation of the bladder. The wounded described by Dupont and Kendirdjy (Case 2), Schwartz and Mocquot (Cases 3 and 11), Stern (Cases 22 and 32), etc., died. The same fate overtook seven of our own cases, and that is easily understood when we

notice that they were nearly all cases of wounds in tne buttocks or in the region of the sacrum where the perforation had been overlooked (hence the operation was too late) or that they were complicated by extensive lacerations and complex lesions of the rectum, the sigmoid flexure, the pelvic bones, etc.

In one case, however, we succeeded in obtaining a recovery in spite of the seriousness and extent of the damage. As far as we know, this is the only case which has been published. It deserves publication, not so much on account of the lessons to be learnt from the point of view of the wounds, as from the method of operation and after-care.

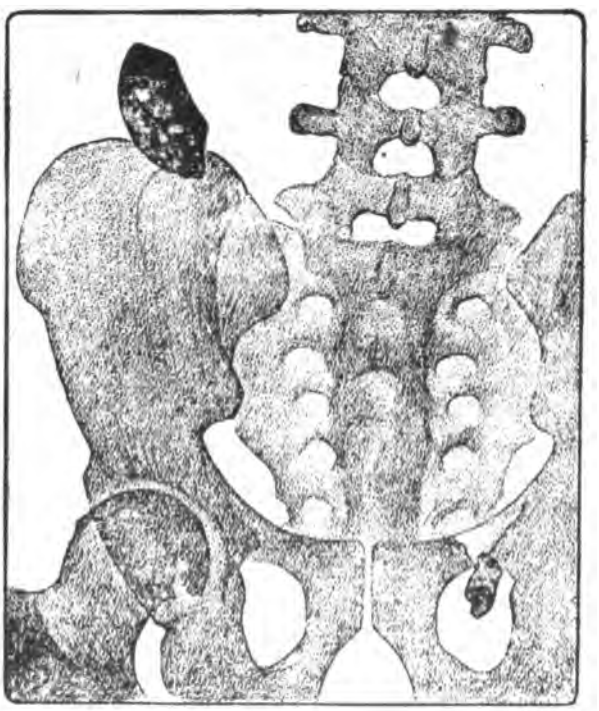


FIG. 64.—Small projectile which has perforated bladder, rectum, small intestine, and pubis. The larger projectile remains sub-peritoneal.

H——, wounded by shell-splinter April 29th, 1915, in the night, was brought to us the same day at nine o'clock. On the left buttock about 3 cm. behind the anus, and invading the region of the sacrum, there was a wound 12 cm. long losing itself in the fold between

the buttocks; copious bleeding. Catheterism of the bladder, a few drops of blood; no urine, abdomen painful, severe shock; bloodless, respiration very faint, pulse uncountable, cold. *Thought to be beyond operation.*

Injections of saline, caffeine, ether, and camphorated oil. Two hours later the patient revived. P. 424

Operation.—About twelve hours after the injury. Continuous injection of saline. Chloroform; severe syncope at the beginning of the operation, which was continued, however, in spite of the apparently desperate situation. Sub-umbilical median laparotomy; copious bleeding from the left posterior surface of the *bladder, which was ruptured* for a length of 25 mm. with subperitoneal hæmatoma and laceration of the bleeding peritoneum; suture of the bladder, large drainage-tube pushed in at the back of the wound towards the buttock and coming out at the hypogastrium; the peritoneum was closed again above, thus shutting off the cavity from the rest of the abdomen. Examination of the intestine; *two perforations of the small intestine* close together, one cm. in length; suture by purse-stitch. The loops of the intestine were washed with a solution of sea-salt, strength 140 in 1,000; 200 grms. of the same solution were put into the abdomen; a large drain into the pelvis; stitching up in one layer only; catheter tied in. Length of operation, fifty-five minutes.

After-effects.—Flatus on the second day, natural stool on the fourth, From the day after the operation, T. 36° (96·8° Fahr.), P. 396, and then fell to 120. On the sixth day urine by the hypogastrium; the catheter constantly obstructed by pus from the bladder; on the tenth day it was left out. May 16th fæcal matter in the hypogastrium; immediate removal of the large drainage-tube; in two days the discharge of fæcal matter ceased, and then that of urine. Urine

and fæcal matter then passed by the gluteal wound. Frequent lavage of the bladder and the wounds. May 25th, micturition normal.

May 26th, fæces no longer discharged except by the rectum.

May 28th, evacuated with general condition very good ; the posterior wound rapidly filled up.

Radiography (May 27th).—First, a splinter 15 mm. long projected into the inner angle of the left obturator foramen. Secondly, a large foreign body was clearly visible in the left flank, against the cæcum, having glanced off laterally, it would appear, to the horizontal level of the posterior iliac crest ; but the most vigorous handling did not produce any visible reaction nor any abnormal projection. A radiogram taken some days afterwards at Bar-le-Duc confirmed the radioscopic examination. (Fig. 64.)

After-effects.—Recovery was uneventful.

Latest Report.—The patient has just been operated on by laparotomy at Guincamp by Dr. Aragon, for the extraction of a large shell fragment (40 grammes of cast-iron) enclosed in a fold of the peritoneum between the cæcum and the lateral external and posterior wall ; the appendix was removed at the same time. After-effects excellent. Complete recovery in all other respects. (Abadie ([33]), Case 15.)

(*h*) **Rectum.**—Isolate if possible from the peritoneum, leave a large opening from the perineum and from the sacrum by opening up the posterior wound, pack with gauze and drain all the corners ; this seems to us to be the general method to be followed.

(*k*) **Omentum, Mesentery, Posterior Peritoneum.**—The omentum contaminated by or perforated with possibly septic tissue should be resected in all the injured parts. The hæmostasis must be watched. The mesentery is often the seat of hæmorrhage ; the ruptured vessels must be carefully searched for. This is often difficult, for a hæmorrhagic infiltration divides

the folds and prevents us from finding the origin of the hæmorrhage.

The perforations and lacerations are sutured after cleaning up and checking the hæmorrhage at the edges of the wound.

We have already seen under which circumstances it is necessary to make the various intestinal resections for lacerations, perforations, and injuries at points of insertion.

Posterior retro-peritoneal hæmorrhage looks like a red tumour. It is useless to seek for the origin of the blood; the most one can do is to plug the region whence it comes. Sometimes one may be induced to lift up the posterior peritoneum and suture it to the edges of the exploratory peritoneal incision, in such a way as to isolate the peritoneal cavity and so effect extra-peritoneal plugging. (C. Wallace.)

(*l*) **Thoraco-Abdominal Wounds.**—Thoraco-abdominal wounds which call for operation are, as a rule, large openings involving two regions, the thoracic and the abdominal, piercing the partition of the diaphragm, which separates them, and penetrating also the walls of the thorax (see Fig. 21).

The edges must be repaired and the costal section made sound by removal of bone-splinters or by resection.

A visceral hernia through the diaphragm should be verified, reduced after the viscera have been cleaned up and repaired, and, if the condition of the patient allows, the operation should be completed by an exploratory laparotomy. In the case-report on p. 379 (Fig. 20), we could not do this; we had closed up one perforation of the stomach, but there remained another, unnoticed, as well as some intestinal injuries.

If the hernia is confined to the omentum it is wiser to leave it alone, as it forms a natural plug, even at the risk of having to perform laparotomy if there are accompanying symptoms of a deep abdominal wound.

It will be advisable, as a rule, to isolate the pleural cavity by joining up the edges of the parietal opening to those of the diaphragmatic opening as we suggest in the case on p. 380 then it is emptied by aspiration.

The Miculicz pleural treatment, according to Depage, has resulted in several cures in the case of large wounds in the thorax, with a complete pneumothorax. The treatment might produce good results in a thoraco-abdominal association.

General Examination of the Abdominal Viscera

When the zone of the injuries is not clearly marked or when there is an impression of a wide area of injuries (and this case is frequent when there is no reliable information as to the course of the projectile), one must at once make a full and methodical inspection of the intestinal mass, and then, if necessary, of the whole viscera.

This exploratory examination is also necessary when the various injuries have been repaired, and the projectile has not been removed at the same time. Unless this is done we are liable to overlook some injuries.

Briefly : *the cases in which we can do without making a complete visceral examination appear to us to be very few.*

The intestine, as one goes on methodically exposing it, is wrapped up in a large compress soaked in hot saline solution. The injuries are isolated, one after the other, as they are discovered and grouped together, under compresses, on the side away from the whole intestinal mass, which is on the left near the assistant, while the lesions are on the right near the operator. They are not treated until later on, otherwise we run the risk of obscuring many perforations, and being forced, after a fuller examination, to resect some loop which we have already repaired with difficulty.

The swabs which surround them are sprinkled with *hot saline*. Depage obtained a continuous sprinkling by a jet of saline from an adjacent receiver; this arrangement cannot always be made sufficiently aseptic in installations at the front; but we can always put two or three thicknesses of compresses over the exposed mass and pour over them from time to time hot saline at a temperature of 40° to 45° C. (104° to 113° Fahr.).

In the examination we must not neglect the region of the colon, still less the bladder.

Removal of the Projectiles.—Here we see the advantage of those equipments which, thanks to the radioscope, are able in a preliminary examination to determine the number and seat of the projectiles.

Though the surgeon must avoid any prolongation of an operation which is not intended primarily to remove projectiles, but to repair the injuries that they have produced, he will have done a more satisfactory piece of work if he has been able to remove the foreign bodies at the same time.

Without information from the radioscope, he will sometimes pass quite close to a shell-splinter without suspecting it, although he would have been only too glad to get hold of it, and so relieve the patient of it at once.

Rochard has carefully elaborated this point and Stern's statistics show a doubled mortality when the projectile is left in the body. How much quicker and simpler would have been the operative results in E——'s case, if we had been able to remove at once a shell-splinter which, by the abscesses which it caused, jeopardised the recovery of the patient for some days!

November 2nd, 1915, E—— was injured by a shell-splinter above the right anterior superior iliac spine; a median sub-umbilical *laparotomy* (at the twelfth hour) allowed the mopping-up of an effusion of fœtid

liquid and of intestinal contents which came from a *perforation of the small intestine* which was sutured. *No projectile was found.* Ether. Double drainage.

November 6th. Normal stool.

On November 11th, pieces of clothing and some pus came away through the upper drain.

November 15th, to the right of the umbilicus, *a large deep-seated abscess was opened.* Under the radioscopic screen the forceps easily found the projectile, but a loop of the intestine probably came in the way. On December 2nd the projectile was taken away; it was a 2 cm. cube. From that moment the healing was normal, and in January the wound was entirely closed. (Abadie [33], Case 3.)

Briefly. When, without lengthening the operation too much, we can find and remove the projectiles, it is best to do so.

Cleansing and Draining the Peritoneum.—The swabbing-up of the abdominal cavity is necessary, especially in the three parts which slope downwards, the flanks and the pelvis. This has to be taken in hand from the very beginning of the operation, and continued in order to make sure that there is no further hæmorrhage.

The organs and tissues near the perforations have been cleansed with ether during the operations for repairs and then covered over with swabs wet with saline. It has become the custom to pour a small quantity of ether into the abdomen after the operation, before closing it up again. Not more than 100-150 grammes must be used.

This proceeding is not without some drawbacks, and one must at once watch for any change of pulse and respiration. The general cold due to the ebullition and the rapid evaporation of the ether must be taken into consideration.

Are we to suppose that no harm comes from the fact that "bathing with ether has the effect not only

of lubricating and drying up the peritoneum, but also of completing the general narcosis and especially of relaxing the loops of the intestines, opening up to the laparotomist, as cocaine-adrenalin does to the rhinologist, a wider field of exploration ? " (Picqué).

For our own part, we have always had more faith in the action of swabs soaked in ***very hot salt saline*** which surrounds or gently wipes the loops ; the colour improves at once. The circulation becomes stronger and the whole appearance is more normal than after ether has been employed ; we can correct the former method by the latter ; by the first we obtain temporary asepsis in a limited area, by the second we stimulate contractility and adhesive power—both indications of normal vitality ; in a very short time the peritoneum will begin to adhere to the swabs.

It is not until the operation is at an end that we leave a small quantity of ether in the pelvis ; its vapour circulating in this particularly septic region may be useful. Moreover, we must mention that, in two cases, we substituted for the ether hypertonic saline solution, 140 in 1,000 ; one of these cases (see p. 517) is perhaps the most successful of the series.

The replacement of the intestinal coils has never seemed to us a difficulty ; it must be done methodically, taking care to avoid any twisting which might lead to obstruction.

Shall we drain or not ? Only in cases of strictly limited injuries easily repaired, and without soiling of the general abdominal cavity, ought we to close up without drainage. Such conditions are exceptional.

We think it wiser to place one drainage-tube in the pelvis and sometimes another near the lesions.

Certain post-mortem findings would incline us to a systematic drainage of the pelvis, in the case of sub-umbilical wounds and of high laparotomy as well as in the case of low laparotomy, if there is proved to

have been hæmorrhage or effusion of fluids from a septic area pouring into the downward sloping parts of the abdomen.

This drainage takes very little time, only a minute or two, and allows of the exit of this suspicious effusion. Examination of the rectum may give, with regard to this, some very useful information, by revealing before operation on the middle or upper part of the abdomen an effusion into the recto-vesical pouch.

Certain operators pack with gauze, at the same time using drainage-tubes, and Stern describes cases where the injured gut was literally swathed in gauze, packed into the point where the gut was absolutely intact; in the centre a drainage tube serves the purpose of allowing daily douches of ether. These swabs are intended to facilitate adhesion. Adhesions between themselves and the intestine, certainly; and this accounts for the almost constant appearance of subsequent fistulas! But one is right to ask oneself why should we set up a barrier of adhesions in addition to that of the swabs? It is very probable that these adhesions (which do not need swabs to produce them) will, on the contrary, be pulled about and injured in the daily cleaning up and dressing with gauze. As to the idea of trying to keep the injured loops near the wound itself it is impossible with widely disseminated lesions, and above all we must avoid abnormal torsion of the gut.

We should do better to push down the injured loop or loops into the pelvic cavity and *to cover up the rest of the small intestine very carefully with the omentum*; the omentum forms a very useful covering if the sutures of the incision give way spontaneously, or if the wound is deliberately reopened by the surgeon. (See cases on pp. 359 and 517.)

Closure of the Abdomen.—Every one is agreed as to this; close up on one plane with a strong metal wire, either brass or silver. With these, we can use horse-

hair threads or Michel's clips, to bring together the cutaneous edges.

The employment of a steel wire in the case of isolated hidden stitches is suggested by Clermont; some years ago I used this method in aseptic surgery; as, however, the elimination was often very slow, I gave up the practice. If we use it after an operation for a penetrating abdominal wound we shall meet with many drawbacks.

Two precautions must be taken: always clean the wound itself very carefully if it is included in the incision, and if possible do not reunite, at this level—leave plenty of space round the drainage tubes and the gauze used for plugging, so as not to compress them unduly.

Treatment of Accompanying Wounds.—We will not dogmatise, and say that we must *always* perform laparotomy and treat the patient's other wounds at the same time; it is a case of diagnostic intuition and of appreciation of the power of resistance in the patient.

But it is very desirable that multiple wounds should be laid open and cleansed, that any accessible foreign bodies should be removed, and the dressings carefully done so that the patient need not be moved for several days.

This method is particularly necessary for wounds in the lower limbs, which, more than any others, are liable rapidly to develop septic complications, notably gas gangrene.

Dressing.—We shall note only the advantage to be obtained by setting up an external siphonage for supra-pubic cystotomy and in certain cases of hypogastric drainage.

Post-operative care—immediate treatment.—As soon as the patient has been warmed, rubbed if necessary, and restored by all the usual means after anæsthesia, the essential points are:

Absolute immobility ;
Fowler's position ;
Nothing by mouth.

These form a therapeutic triad which we will consider in detail under "medical treatment."

At the same time we give daily injections of camphorated oil (10 cc.) ; of adrenalin in doses of 2 or even 3 milligrammes decreasing to ½ a milligramme, which is continued as long as there is low arterial tension.

Finally, if there should be pulmonary congestion, strychnine.

Usually, we give the patients small doses of morphia : ½ centigramme morning and evening.

(One *ought* to be able to isolate in a separate room.)

Operative after-treatment. Dressings.—We will give an outline of four different types.

With some patients everything follows a normal course. From the second day recovery would appear to be almost certain ; pulse slower and fuller, the face calm and the eyes brighter, no restlessness of any sort, nor the calm induced by torpor. On the third to the sixth day flatus or natural stools appear, the stitches are removed, and union takes place from the outset.

In a quite contrary case the weakness remains or increases ; after the operation, the pulse quickens, the features are drawn, dyspnœa increases and the end comes rapidly in the first thirty-five or forty-eight hours. A fatal development of this kind occurs in the large majority of these unfortunate cases ; and against it we are utterly helpless.

Others, less frequently, are carried off in four to six days by typical general peritonitis, acute no doubt, but with a relatively slow development. And we are almost powerless.

In a great many cases recovery is only obtained at the price of a sustained struggle. No other kind of

patient demands such assiduous care and such attentive observation of detail in order to discover the complication in time. Laparotomy for abdominal wounds derives more benefit from the "dodges" for treatment which the surgeon's own personal experience will suggest than any other operation.

The day after the operation it will be wise to look over the dressings in case it is necessary to move or change the gauze plugging or to draw off the serous fluid in the pelvis by means of a Nélaton catheter introduced right into the opening of the drainage tube, or to examine the line of suture; in cases where the incision passes actually into the wound itself, be on the look-out for gas gangrene! If one day be lost, it will be too late! And if the edges of the wound are turgid, or if when a stitch is taken away we notice that the tissues are violet or green, we must not hesitate to open the wound again; there will be protrusion as a matter of course, but it is only at such a price that some hope of a cure can be retained (see pp. 495 and 517.

Dressings should be done every day, or at least every two days. We cannot go into every detail, but one or two points must be insisted on.

The *respiration* must receive special attention; from the moment that we have ascertained the existence of pulmonary congestion, we must use cupping, mustard poultices and strychnine.

If there is regurgitation, sickness or distention, the *stomach should be washed out.* This gives instant relief.

In the case of supra-pubic cystotomy one must not hastily *tie in a catheter*, but wait until the hypogastric opening is almost closed. Unless this is done the urethra and the bladder will both be fatally infected. Sometimes a tied-in catheter is quite unnecessary and, as after prostatectomy, micturition will re-establish itself naturally. It may be useful to arrange a *continuous irrigation* of the recto-vesical pouch; to do

this one passes a Nélaton catheter the whole length of the pelvic drain. One of our patients began to improve in a few hours after a triple system of instillation tubes had been set up ; instillation in the bladder by means of a fixed catheter with supra-pubic drainage ; instillation in the pelvis with hypogastric siphonage and rectal instillation.

When there is distension we apply *the wet compress of Priessnitz*, in preference to ice. We shall come back to this in dealing with medical treatment.

When the patient is convalescent we apply *heliotherapy* to the wounds themselves, and the abdominal walls.

In the case of *protrusion* a strip of adhesive plaster to the borders of which hooks have been sewn is stuck along each edge ; above the swabs of gauze protecting the wound, a piece of catgut, silk, or elastic draws the hooks together, and thus the edges of the wound are united. The diameter of the *drainage tubes* is gradually diminished and then they are shortened.

The cases we have quoted above (see pp.359 and 495) give examples of various kinds of operative results.

Every surgeon must surely remember patients whom he has not only saved in the first instance by laparotomy but for whom he has afterwards fought with death for a long time ; the surgeon must be stubborn and never allow that he is beaten ; the patient must also "hang on" to life, and struggle with confidence and resolution.

Evacuation.—This much-debated question is entirely dominated by one fact : for patients who have undergone visceral laparotomy, there is always a *critical period* from the sixth to about the fifteenth day ; it is at this time that the sutures are liable to come apart, that fistulas appear and that the abdominal walls give way.

Experience confirms this.

One of Goinard's patients got up on the ninth day

to go and get a drink of water; he developed disquieting peritoneal symptoms.

A patient of Schwartz at the sixth day got up in the night to see a fire; a fatal attack of peritonitis resulted.

Four patients on whom Proust performed laparotomy were evacuated from Aubigny to Paris between the sixth and the twelfth day: one died; the second developed distension of the abdomen, vomiting and diarrhœa, and the other two were very exhausted.

Quénu insists then quite rightly on the injuriousness of all transport during this period.

The question of evacuation therefore may be summed up thus:

If the wounded who have been operated on at the advanced stations are unable to remain in hospital on the spot for at least fifteen days, they ought to be evacuated during the first four days to the nearest stationary surgical ambulance, that is to say one about 12 kilometres from the front. It was in this way that we received Bouvier's and Caudrelier's patients in our hospital at Sainte-Menehould; they made perfectly normal progress towards recovery.

The patients operated on in the stationary surgical ambulances ought to stay in the same place for at least fifteen days or longer still if they should develop any complications. Only in a case of urgent necessity should a laparotomy patient be moved between the sixth and the fifteenth day; he will run great risks, but not actually great enough to be equivalent to a death sentence.

How shall evacuation to the hospitals of the interior be carried out? Stern and Rochard propose short stages by hospitals situated at places only a few hours apart. We can understand the advantages of having only such a short journey to make in going from a stationary ambulance to the farthest hospital centre. But it would appear to be better to leave the patient there to rest three or four days longer, and then send him

direct to the final hospital, rather than take him to two or three more supplementary stopping-places under the pretext of not giving him more than three hours on a railway. In doing so we are overlooking the shiftings inseparable from every new journey; dressing, placing in the automobile, transference from auto to train, transference from train to auto, journey in automobile, unloading, and undressing. If "three removals are as bad as a fire," three transhipments are worse than one long railway journey! From the line of communications, the patient ought to go directly to his ultimate destination.

Finally the possibility of future complications ought to cause us to hesitate in making premature estimates as to recovery. It is only in the *final* hospital that any safe prognosis can be made.

CHAPTER IX

MEDICAL TREATMENT—EXCEPTIONAL OPERATIONS—DEFERRED OPERATIONS

THE medical treatment for penetrating wounds of the abdomen may be stated as briefly and clearly as an equation; this has the advantage of enabling it to be applied automatically by those in charge of the wounded.

Abdominal wounds without operation =
- Absolute immobility;
- Nothing by mouth;
- Fowler's position;
- Rectal injection "drop by drop";
- Priessnitz's cold compress;
- Morphia;
- Camphorated oil.

Let us review these various factors and notice the rare cases from which they would be excluded, and above all the details of application.

Absolute immobility.—This allows of no relaxation. The less the patient moves or is moved, the better it will be. Complete isolation, if it could be procured, would be the ideal treatment.

Nothing by mouth.—An equally obvious precept. But intense thirst and dryness of the mouth when they do not yield to injections of saline and a rectal injection may lead to some relaxation of this rule. But a spoonful of cold water every two hours is all that can be allowed; sensible patients will be content with only rinsing their mouths with this water. If there is the

least tendency to vomiting even this slight relaxation must be withdrawn.

At the end of four or five days, if the recovery is following a normal course, the dose of liquid may be increased at longer intervals; tea with rum hot or cold, as the patient prefers, and whichever agrees best with his stomach; then broth and aerated water, and

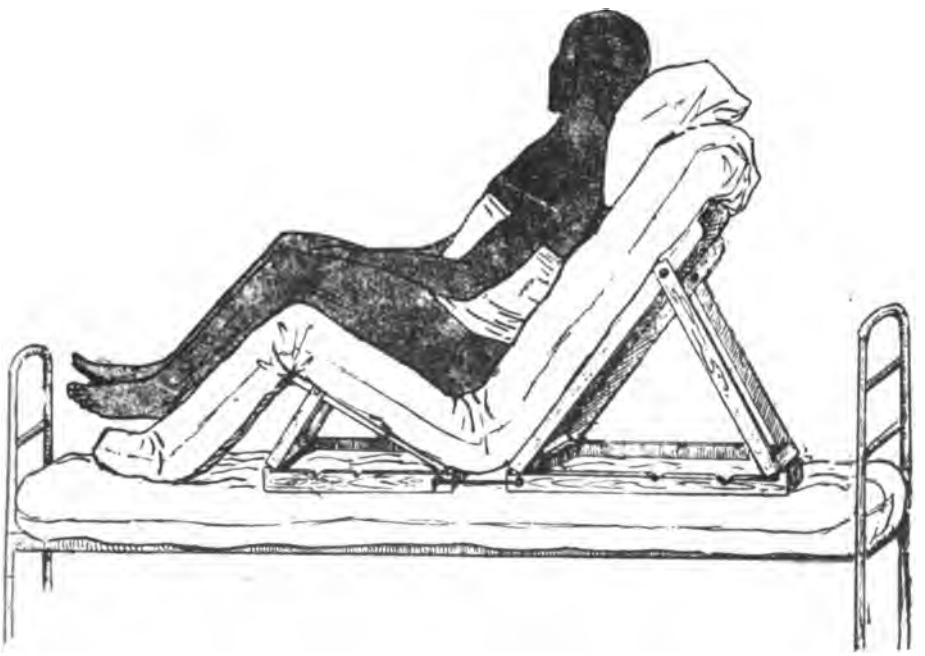


FIG. 65.—Showing arrangement in Fowler's position with the help of two inclined planes fixed together.

then milk mixed with Vichy water; finally, light purées and custards, etc.

Fowler's position.—This is produced by means of an inclined plane and long cushions or a mattress, or better still with two inclined planes hinged together, of which one, intended for the seat, is shorter than that supporting the back. We find this arrangement more convenient and more resilient than a framework of two inclined planes in one piece. Fig. 65 shows a

side-view of this arrangement. A long cushion may be added to support the loins and make the patient comfortable whilst resting in this position.

In certain flank wounds the lateral decubitus will have to be substituted for Fowler's position and the

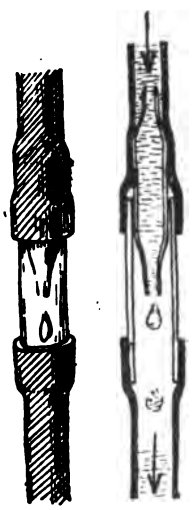


FIG. 66. — Drop-counter for controlling the "drop-by-drop" rectal instillation. Extemporised by means of an ampoule for hypodermic injections aud a glass tube in which catgut ligatures are stored.

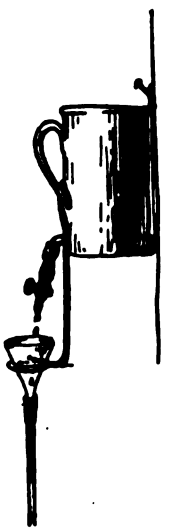


FIG. 67.—Control of the "drop-by-drop" apparatus by means of a funnel (Stern).

FIG. 68. — Regulation of the "drop-by-drop" instillation by progressive pressure on a rubber tube, under a piece of wood tightened up by a screw-ring. (The piece of wood may be placed horizontally, which would do away with the need for supporting the rubber tube by a V-shaped iron wire.)

dorsal decubitus for penetrating wounds of the upper region.

Rectal injection "drop by drop." This is obtained by means of a Nélaton catheter connected with a douche can.

To regulate this we may use many little devices.

Regulation by means of a simple ebony stop-cock without control is one of the most difficult. We may apply control either by the insertion of a drop-counter (see Fig. 66) connected with a hypodermic injection ampoule and a glass catgut tube, or by using Stern's method with a funnel (Fig. 67). Regulation can never be effective unless it is obtained slowly with the help of a tightening screw. The indiarubber tube can be tightened by degrees (Fig. 68). On the other hand, it is possible to reduce the pressure on the branches of a Tripier's dilator Heister's gag or a nasal speculum by the constriction due to a rubber ring (piece of tubing) bringing the ends of the branches together.

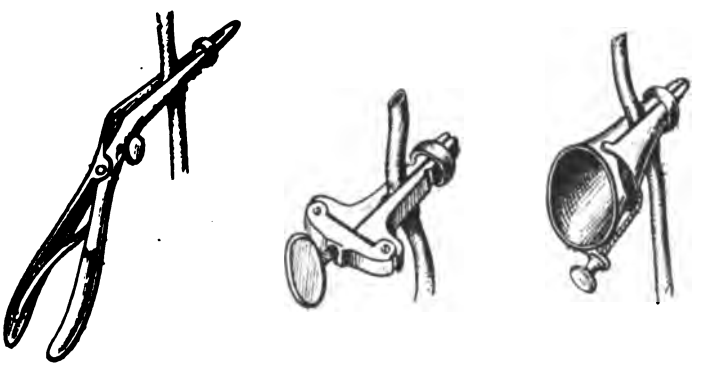


FIG. 69.—Different improvised arrangements to exert gradual pressure on an indiarubber tube and thus to obtain easily a drop-by-drop injection with the instruments fitted with a regulating screw which are to be found in all surgical outfits (Tripier's dilator, Heister's gag and a nasal speculum). The screw serves to reduce the pressure produced by a rubber ring surrounding the ends of the instruments used.

We show above all the improvised arrangements which are in daily use and do not require any patent dropping tube.

What quantity of liquid ought to be absorbed? Four to five litres a day seems to us a maximum, and a drop-by-drop injection of 15 to 20 litres seems questionable. What we want to procure is absorption. Of what use could it possibly be to induce a repletion which

produces evacuations from the rectum, and which may cause unnecessary and even injurious contractions of the intestine? In addition we might consider the question of perforated mattresses and the patient's uncomfortable position. But we are speaking of medical treatment during war.

Priessnitz's compress.—We prefer to use this rather than ice. This is not only on account of its practical utility, though we ought to remember how rare it is under war conditions, to be able to obtain ice, while it is very simple at all times to surround the abdomen and the loins with wet swabs. But for some years past we have entirely given up the use of ice in pelvi-peritonitis, and even in appendicitis itself, and we believe we have obtained better results with Priessnitz's method.

The wet compresses ought not to be confined to the abdomen, but ought to be arranged all round the waist. Two napkins soaked in cold water and wrung out, or a large dressing saturated with water, are placed round the abdomen and the kidneys; we then cover over everything with waterproof and keep it in position with a bandage round the body. This "pack" is renewed every twelve hours.

Morphia should be given in small doses, but the patient must be kept continuously under its influence: two daily injections of ½ centigramme or even up to 1 centigramme will be enough.

Camphorated oil is an excellent heart tonic; but this must be given in large doses: 1 gramme of camphor a day as a rule or even up to 2 grammes.

This is the principal treatment. But we must not hesitate to add (according to the symptoms) subcutaneous injections of saline in addition to the rectal injection, or to have recourse to adrenalin in the presence of marked reduction of tension.

Possible after-effects.—After this treatment three contingencies may follow:

(*a*) Either at once, or after some days during which the pulse and temperature have remained high and the signs of abdominal reaction are marked, the general condition improves, the peritoneal syndrome subsides, flatus is emitted voluntarily, and recovery gradually takes place uninterruptedly.

(*b*) The initial peritonitic condition declares itself frankly as peritonitis; and is followed by increased contracture, distension, bilious vomit, becoming dark and brown, weak pulse, agitation, and dyspnœa.

Death takes place between the third and the eighth day.

(*c*) After a period of abdominal reaction of a variable but temporary intensity, the development appears favourable, and there is a decided improvement. Recovery seems certain, but towards the sixth, seventh or eighth day the general condition becomes less good; the face is again drawn, and the pulse rapid; but the feverish complexion, and the agreement between the pulse and the temperature, which has risen to 39° C. (102·2° Fahr.), show that the patient is putting up a good fight and defending himself. Deep abdominal pain, diffused or localised, leads us to make a new and searching examination, and we discover localised peritonitis, or even a collection of pus in the iliac fossa, the pelvis or under the diaphragm.

And in this case we should perform, not perhaps laparotomy but one of the operations which we still have to describe: Murphy's supra-pubic drainage, lateral drainage, or multiple drainage.

The *evacuation* of patients with abdominal wounds which are under medical treatment necessitates the same precautions as for those who have undergone laparotomy, and there is the same critical period from the sixth to the fifteenth day during which evacuation should not be thought of. This period once over, all now depends upon the regularity of development.

Unusual Operations

Murphy's supra-pubic drainage.—In order to get the best out of this operation, we must avoid general anæsthesia either with chloroform or ether. In the last extremity we may have recourse to general anæsthesia with kelene or ethyl-chloride, but given progressively and slowly in small doses and not much at a time; otherwise the patient will often struggle and highly dangerous effects due to movement and strain may result. It is undoubtedly best therefore to use *local anæsthesia* with novocaine or stovaine; anæsthesia of the skin for 6 cm. on the median line and subcutaneous injections of 1 c.c. in both recti.

The whole operation scarcely takes two minutes.

The bladder having been emptied, an incision 5 cm. long is made in the skin along the median line; the aponeurosis between the two recti is cut open, and we make a horizontal cut with the scissors of about 1 cm. in length, in each tendon of the insertion of the recti; a small autostatic retractor or two of Farabœuf's retractors expose the peritoneum, which is then seized by two Kocher's forceps; an incision is made, and we use a retractor or simply the closed scissors to lift up the loops of the small intestine, and a long curved clamp, holding a wide-bore drainage tube between its points, is used to introduce the tube gently into the recto-vesical pouch. It will be advisable to suture it with horsehair to one of the lips of the wound.

The drainage tube carries away blood, intestinal fluids, bile, fœtid serous matter, and pus.

Certain authors advise injection through the drain, of ether or camphorated oil. But the most important thing seems to us to be steadily to get rid of the septic fluid collected under pressure.

That the evacuation of such fluids may be as complete as possible, the simplest method is to fit the

drain with a siphon tube plunged into a bottle filled a quarter of the way up with antiseptic solution. Aspiration is as complete and more continuous than when done by a syringe.

Murphy's operation ought to be followed by medical treatment.

In addition the patient must be regularly examined. We have mentioned that the early formation of adhesions soon frustrates drainage of the abdominal cavity by the recto-vesical pouch. We must then detect the areas of local peritonitis in time and operate in order to drain them. Chalier was thus led to make a right lateral laparotomy on the thirteenth day in order to drain a large sub-phrenic abscess which contained 3 litres; death followed nevertheless.

The drain is removed gradually, first by diminishing its calibre, and then by reducing its length in proportion as it discharges less and thinner pus, that is to say between the sixth and the tenth day.

Multiple drainage.—Sencert insisted, at the Congress of Surgery in 1900, on the value of multiple drainage in the hypogastrium and in the iliac fossæ. He proposed "small" peritoneal incisions, as they would drain better than the larger ones on account of the abdominal pressure.

Ileostomy.—Colostomy.—Anastomosis of a loop of the small intestine to the skin may be made in the course of a laparotomy which, owing to the general condition of the patient, has not followed a normal course.

This may occur with a loop already perforated and where the false anus is already established; it will be enlarged either naturally by the sloughing of a strangulated loop, or by an incision with the cautery made by the surgeon. Deliberate ileostomy as recommended by Miramond de la Roquette for the sole reason of allowing the easy evacuation of the contents of the bowels, and thus diminishing the distension of the

loops, is quite different. We have said (p. 389) what we think of this operation. Without a technical description we cannot represent it exactly.

Iliac *colostomy* is a useful addition to an operation in certain cases of injuries to the rectum when we desire to isolate it in order to facilitate subsequent disinfection and reparation. Granted that the case is not one of immediate evacuation, the simplest method, and therefore the best, is to separate off the gut with a packing of gauze or a simple drain passed underneath it. Next day or the day after it is opened.

Drainage of localised peritoneal abscesses.—Collections of pus due to encysted peritonitis should be opened the moment they are discovered. We may distinguish ·

(*a*) Sub-phrenic abscesses following wounds of the stomach, spleen, and liver.

(*b*) Sub-hepatic abscesses from wounds in stomach, spleen and liver.

(*c*) Abscesses in the iliac fossæ which are reached by the incision for acute appendicitis or for the ligature of the external iliac.

(*d*) Abscesses round the bladder, opening on to the hypogastrium or by way of the rectum.

(*e*) Abscesses pointing in the buttocks or the perianal region.

(*f*) Pelvic cellulitis which may necessitate an operation by means of the methods of perineal prostatectomy, or a sub-peritoneal laparotomy or a rectal incision or even sacral resection.

(*g*) Abscesses round the kidneys reached by the incision used ordinarily in nephrectomy.

(*h*) Collections of pus behind the colon, in which Wallace has shown the danger of early gaseous infection, progressive septic infiltration or septicæmia. Here also lumbar laparotomy is called for.

(*i*) Abscesses in the lesser sac of the peritoneum caused by suppurating hæmatoma ; these are difficult

abscesses to diagnose, and will necessitate a complete laparotomy.

Deferred Operations

Deferred operations are those which deal with the results left behind by penetrating wounds of the abdomen, or by the laparotomy which they have required.

Delayed removal of the projectiles requires a searching preliminary radioscopic examination; this may disclose hitherto unsuspected foreign bodies, whose appearance is a real surprise. One of the most curious instances is that of one of Delore's patients [67] in whose body a pile of *six louis d'or* was found, which had been forced through his waist-belt by the projectile, carried into the abdomen and thence had fallen into the recto-vesical pouch.

Gouilloud and Arcelin [75] have written an article on "mobile and stationary bullets in the abdominal cavity," from which we have taken the two drawings of shrapnel bullets embedded in the omentum. A rifle bullet removed by Quénu [71] had entered the abdominal cavity by the sacral region, without affecting any visceral organ; it had become encysted in the omentum. The fluid of the cyst, though its virulence lessened, did not become quite sterile; even after a year, it still contained staphylococci.

In one of our own observations, the discovery of a large shell splinter in the right iliac fossa was an equally surprising result due to the radioscope.

Mauclaire [60] took away, at the level of the ileo-cæcal angle, some fragments of a bullet, which were causing persistent pain, from a patient who had undergone Murphy's treatment.

The method of these operations varies for each case.

Protrusions of the intestines are frequent after laparotomy; either because we have had to leave openings large enough for plugging or because it has

been thought wise not to close up a penetrating wound with contused and septic edges, or because the edges of a laparotomy wound have become separated.

Very few cases have as yet been published. We will quote, however, a case by Walther [75] relating to a very large left sub-costal intestinal protrusion.

A bullet which went in above the left iliac crest came out at the front under the costal margin after having gone through the colon, as was shown by a fæcal fistula lasting for five months. Dissection showed the orifice of the hernia to be from 8 to 10 cm. broad, and 5 cm. high. It was repaired by a series of U-stitches in double horsehair, independently of the suturing of the peritoneum by catgut.

The closing of an artificial anus following on an abdominal wound is easily managed, as Quénu [64] remarks, by the following method: free the edges of the anus, separate the two edges of the abdominal wound and lay bare the aponeurosis of the external oblique muscle. Then the two fragments of the intestine are seen in the shape of two cylinders covered externally with fat; we anastomose them by passing non-perforating threads from one to the other, and doubling this first plane of sutures by a second which passes through the muscular and fatty tissue of the intestine. If the peritoneum has been opened in setting free the intestine it is sewn up by a purse-stitch; the two sutured fragments are pushed behind the muscular-aponeurotic plane of the walls and a catgut suture is made leaving just room enough for a small drain whose end is placed in contact with the intestine. This is a safety drain; on the eighth or ninth day it may occasion a slight discharge with a fæcal odour, but this is of no importance. Thus the cure of an artificial anus by operation is generally effected at the first attempt and is quite without danger.

P. Duval [64] has, for a large lumbar wound with multiple colic fistulæ, deliberately used the method

of *exclusion of the large intestine on the right*, and then *excision of the right colon.*

Finally, here are two examples of complex operations which we may be obliged to perform to counteract *unexpected symptoms due to stenosing cicatrices.*

One of Gosset's patients [73] was injured by a bullet which went in above the right nipple and came out outside the left anterior superior iliac spine. He was treated by Murphy's process, which resulted in a discharge of blood, and then he recovered. But four months afterwards he gradually developed progressive jaundice, which was complicated by septic biliary symptoms which from time to time became very serious. At first a simple drainage of the gall bladder was effected by cholecystotomy; three months later the flow of bile into the duodenum was re-established by *cholecysto-gastrotomy*. According to evidence obtained from the operation, it does not appear that the bile duct was ever injured by the wound; jaundice did not appear until three months later, but the duct, as a secondary consequence, had been enclosed in an area of plastic sub-hepatic peritonitis, itself a result of a probable perforation of the duodenum.

In the case of a patient operated on by Pauchet [74], the stomach, pierced by a bullet, was enclosed in a layer of perigastritis, on its anterior and sub-hepatic surfaces. After the adhesions had been broken down, *the interposition of the coli comentum* prevented any further adhesions being made.

In the months and years to come many other unforeseen cases will doubtless show that the management of penetrating abdominal wounds is not concerned with the immediate treatment alone; at the same time we must insist that the most arduous and fascinating task is that of winning the battle during the early hours, and for this, as we have seen, laparotomy offers us the best weapon.

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SECTION III

WOUNDS OF THE SKULL AND BRAIN

PART I

WOUNDS OF THE BRAIN

CHAPTER I

EXAMINATION OF A PATIENT WITH A WOUND OF THE SKULL

I. Interrogation of the Patient

THIS interrogation should be carried out as minutely as possible. The scheme here suggested should be modified and, especially, extended according to the site of the wound under consideration.

The exact circumstances in which the wound was inflicted and the earliest symptoms experienced.—The first question will be the exact date of the wound and, approximately, the hour? What was the soldier doing at the time? Was he erect or recumbent? Was he wearing a trench-helmet or a cap? What was the position of his head? By what kind of projectile was he wounded—rifle bullet, machine-gun bullet, shrapnel, shell-splinter, or grenade? Was there violent impact, or mere shock without any apparent wound, which is by no means unusual. The patient is frequently unable to give more than very incomplete details on these points.

What were the sensations of the patient at the moment of being wounded? Did he lose consciousness immediately? If not, what were his sensations? Did he feel a violent blow on the head? Was there numbness or instant paralysis of the whole of one

side of the body? Was there total loss of speech? Was there loss of sight, and was it preceded or not by an appearance as of flames before the eyes? Was there a ringing or a buzzing in the ears? Did the patient lose consciousness at once; if not, when did he do so? How did he fall? Patients who do not immediately become unconscious are able to give fairly exact information as to their sensations in the short period during which they retain consciousness.

How long did the patient remain unconscious? Where was he when he recovered consciousness? How long does he think it was before he was picked up?

What were his sensations in his head on recovering consciousness: severe headache, vertigo, little diminution of sight or much, even to actual blindness? Was he deaf?

Could he speak? Could he find the words to express his meaning? Did he babble so that he could not be understood? Did he understand what was said to him? (It is necessary to be cautious in accepting the statements of patients on this point, as they are frequently mistaken as to their power of comprehension.) How many days elapsed before he recovered the power of speech? Has he any difficulty of utterance at the time of the examination; if so, what is its nature?

Was the patient paralysed? Could he use his leg or his arm? What movements could he execute in bed? It is necessary to press this point closely. The patient will often reply that he could not use either arm or leg, and the inference is that there was total hemiplegia. For instance, the patient, while lying in bed, will say that he can move neither arm nor leg. It is necessary to particularise and to ask him if he can move his fingers, take hold of a

glass or a spoon with either hand, whether he can move his toes, bend or stretch out his leg in bed, raise it, etc.

On which side was the paralysis of the limbs? On the side opposite to the wound, or on the same side (homolateral paralysis)?

Were the sensations in the limbs painful or merely unpleasant? Could he perceive objects taken in the hand, contact with the bed-clothes or with a bowl of warm water?

Has the patient experienced any special awkwardness in the use of his arm or leg? Was there intentional tremor? It is necessary to ascertain by inquiry whether there were paralytic as opposed to ataxic or asynergic phenomena. It is often very difficult to get exact replies on this very important point.

Was there any disturbance of urination; if so, was it urgent or difficult?

Was there any disorder of vision, and of what nature? Did the patient see double; for instance, two heads on each of the people around him, which is not uncommon in all varieties of wounds of the skull. Was there blindness, or considerable diminution of vision? Was his sight misty, or did everything appear darkened? Did he see flames or sparks before his eyes?

Could the patient hear well with both ears, or with one only? Was there singing in the ears?

Was there difficulty when eating or drinking?

Had he difficulty in swallowing?

It must be understood that this inquiry is intended to be modified according to the patient's replies, and must be modified according to the site of the wound; thus in the case of a wound of the occiput, special attention must be given to the visual phenomena.

Course of the wound and of the nervous symptoms.—How long was it before the patient could stand up? Had he headache or vertigo? Could he walk without help, or only with the aid of crutches or sticks?

Has he had one or more surgical operations: did these take the form of trephining, extraction of the missile, or plastic operations? Did the wound bleed much? Was a dressing kept on for long? Did it suppurate for long? It is frequently impossible to get precise answers as to the treatment, and in such cases the hospital card which the patient often has with him will furnish information in a very brief form, the slightest surgical treatment, such as the enlargement of the wound or the cleansing of it being entered as "trephining." It is especially necessary to be very sceptical in regard to the extraction of the missile. The patient will say that the projectile has been removed, and may even produce it, and the hospital card may bear the entry: "extraction of missile." Nevertheless there should always be a fresh radiographic examination. In many cases which have come under notice this has shown the presence in the brain of a missile which had escaped notice.

The interrogatory will be closed by asking the patient what troubles he complains of at the time of the examination. Stress need not be laid on such evident signs as hemiplegia, monoplegia, disorders of speech, disorders of vision, which will be made the subject of an exhaustive examination later. He should be questioned as to the subjective disturbances which occur in nearly all cases of wounds of the skull, which may exist alone and require to be investigated in detail. This will be fully dealt with later.

II. Objective Condition of the Wound at the time of Examination

As we have already stated, the cases which come under examination are surgically cured, consequently in nearly all of them the cranial wound will have healed.

The scalp wound.—The scar may be smooth, clean, and hard; or thin, with a tendency to hernia of the brain; or depressed, or irregular (especially after crucial incisions), with hair follicles included in the furrow; on the other hand, the wound may be incompletely cicatrised, with an oozing surface, especially in the case of irregular scars; owing to hairs being entangled in the depression there remains a slight superficial cutaneous infection, and there may even be a small persistent sinus, from which a drop of pus exudes. This sinus is usually the result of a subcutaneous fragment, and calls for surgical cleansing of the wound and removal of the piece of bone.

Loss of bone.—There is naturally great variation in size and shape of the defect, and it is advisable to measure both dimensions with a rule or compasses.

Palpation allows one to ascertain fairly clearly whether we have to deal with a superficial wound only involving the soft parts, or with a furrow in the external table, or with a loss of bone of varying size, with or without spontaneous pulsation, and with or without an impulse on coughing. In certain cases it is difficult to detect the pulsation or the impulse on coughing by palpation alone [1]; the patient may then be told to blow his nose violently, or to bend his head forward very forcibly. The neck may also be lightly

[1] Care must be taken not to confuse a contraction of the temporal muscle or a movement of the epicranial fascia, which may be produced by coughing or the act of blowing the nose, with a tendency to bulge.

forward, the fissure of Rolando being far forward and nearly vertical.

In the occipital type the brain seems to have been tipped backwards on an axis passing transversely through the external auditory meatus on each side, the fissure of Rolando is far back, its posterior ex-

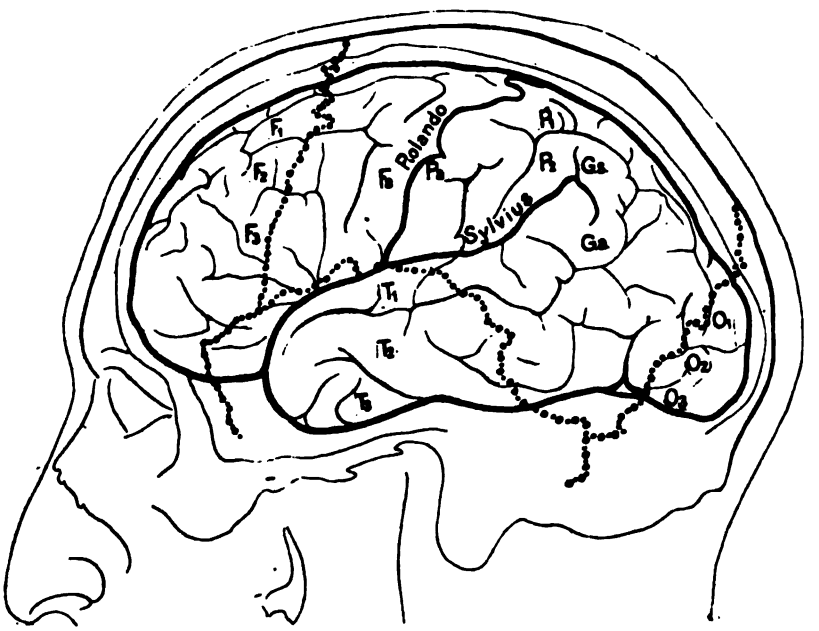


FIG. 2.—Occipital type of skull. The brain is pushed backwards round an axis passing through the auditory canals. The fissure of Rolando is oblique behind, the Sylvian fissure is nearly horizontal, the external occipital protuberance is situated very low down.

tremity being very oblique, and the other fissures are similarly carried backwards and similarly inclined towards the horizontal. In this latter type the whole of the occipital portion of the cranium (the portion of the cranium behind the auditory orifice) is much developed in length, and the external occipital protuberance is very low down. It may be said, generally, that a short skull belongs to the frontal type,

and a long skull to the occipital. The breadth of the skull is of relatively slight importance in determining the direction of the principal fissures.

These general principles have been stated before dealing with the methods of exact cranio-cerebral topography, because they will prevent grave mistakes being made when there is no time or facility to take exact measurements.

Putting aside any attempt to give a full description of the numerous methods of cranio-cerebral topography, our attention will be confined to the most simple and effective, which can easily be practised on any patient, and we shall then pass on to the most recent methods which are based on radiography.

The metrical system of datum-points applied to the living subject.—The method of obtaining datum-points in cranio-cerebral topography is based on knowing how to find certain datum-points which can be felt upon the skull in the living object.

To find the datum-points.

1. *The nasal point.*—This is at the bottom of the naso-frontal angle, which is more easily defined than the glabellum (the prominence above the root of the nose and between the eyebrows), which is usually selected for this point. Besides, the measuring tape can be fixed more steadily at the bottom of the naso-frontal angle than on a prominence which it is often difficult to locate precisely.

2. *The external occipital protuberance* (*inion*).—This is generally easily found by palpation.

3. *The lambda.*—This is the point where the sagittal suture meets the two parieto-occipital sutures, and is the only point where the suture lines of the bones of the skull can be used as a datum-point. It is generally marked by a slight depression caused by the boss of the superior angle of the occipital bone. When there is difficulty in locating the lambda, the lambdoid

suture can be found by measuring off 7 centimetres above the external occipital protuberance along the median line.

4. *The external auditory meatus and the zygomatic arch*, the contours of which can be easily felt, are

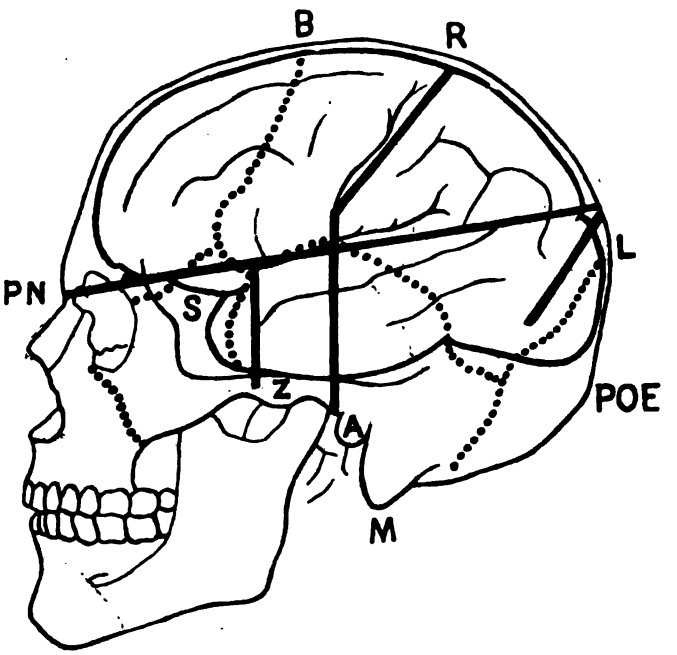


FIG. 3.—The exocranial datum-points and the surface markings of the principal fissures. NP, nasal point; B, bregma; R, upper end of the fissure of Rolando; L, lambda; POE, external occipital protuberance; M, mastoid; A, external auditory meatus; Z, zygoma; S, anterior end of the Sylvian fissure; PNL, Sylvian line.

likewise valuable datum-points, particularly for localising the lower end of the fissure of Rolando.

To map out the fissures.

1. *The fissure of Rolando.*—The position of the upper end of this fissure can be found by taking half the distance from the naso-frontal angle to the inion measured on the antero-posterior sagittal line and

adding 2 centimetres thereto. In practice the distance from the root of the nose to the inion is measured with the tape, the number of centimetres divided by 2, and 2 centimetres added to the dividend. This can be checked by measuring off 18 centimetres along the sagittal line, starting from the root of the nose. The points found by these two measurements will always be found to correspond very closely.

To ascertain the point on the skull corresponding to the lower end of the fissure of Rolando proceed as follows :—

On the zygomatic arch, immediately in front of the auditory meatus, erect a perpendicular; start from the zygomatic arch and count off 7 centimetres; this point will correspond to the inferior extremity of the fissure of Rolando.

This observation may be checked thus: Produce this perpendicular to the sagittal line; starting from the auditory opening, mark off one-half the length less 1½ centimetres; this will give the lower end of the fissure of Rolando. The points obtained by these two measurements very nearly coincide.

2. *The Sylvian fissure.*—Starting from the naso-frontal angle, stretch the measuring tape along the lateral aspect of the cranium 6 centimetres above the external auditory orifice to a point 1 centimetre above the lambda; this is the Sylvian line, which follows the Sylvian fissure along nearly its whole extent.

On this line 7 centimetres from the lambda will be found the gyrus angularis, and at 10 centimetres the gyrus supra-marginalis. The anterior end of the Sylvian fissure can be located by erecting a perpendicular from the centre of the zygomatic arch until it touches the Sylvian line. This point also locates the head of the third frontal convolution.

A point on the sagittal line approximately 1 or 2 centimetres above the lambda corresponds to the

upper end, on the convex edge of the hemisphere, of the external perpendicular fissure which divides the external aspect of the occipital lobe from the parietal lobe ; the variations are fairly wide. A perpendicular to the sagittal line let drop from this point will give the course of the external perpendicular fissure along the convexity of the hemisphere.

These simple rules for locating the course of the

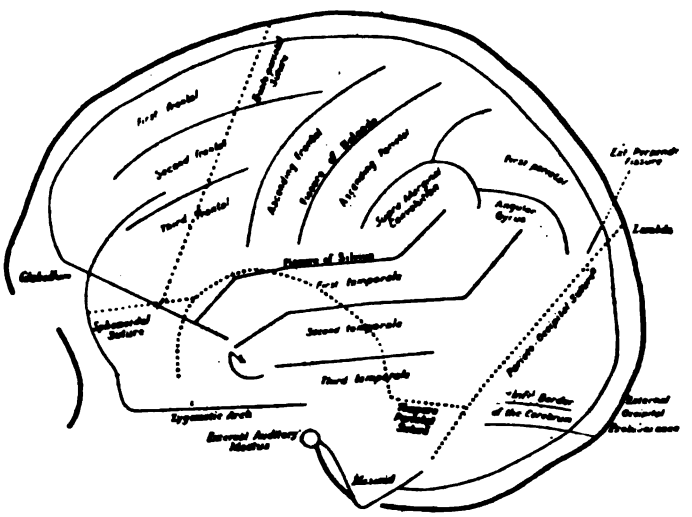


FIG. 4.—Radiographic projection of the cranial sutures and the cerebral fissures and sulci from a radiograph in a fixed position by M. Infroit. Patient seated, plate parallel to the sagittal plane, tube at 50 centimetres (Pierre Marie, Foix, and Bertrand).

principal fissures by means of a measuring tape will be found amply sufficient, in practice, to locate the site of a wound relatively to the principal fissures and the principal centres of the cortex.

The application of radiography to cranio-cerebral topography.—By means of radiography it is possible to ascertain definitely the relation that the loss of bone bears to the subjacent cerebral convolutions.

We have made use of this method in the study of

wounds of the visual area (see Chapter VIII.). The technique of this method has since been worked out in detail,[1] and applied to the study of the fissures and convolutions of the outer surface of the brain. A description of the method employed would take up too much space, and readers must refer to the works mentioned in the footnote, but it is based essentially on the following procedure: A prepared brain is removed from its cranium, and the convolutions marked out with leaden wires; the brain is then returned to the cranium, and the whole radiographed in accordance with certain stringent rules, which we shall state later on when dealing with the radiography of wounds of the skull. From the radiographs of variously shaped brains marked out thus with the lead wires a normal topographic plan can be mapped out, which can be laid upon the radiograph of any patient's skull. It can then be seen to which convolution or fissure the loss of bone corresponds. This method can only be employed after constructing a normal plan, and by radiographing in identical positions and at identical distances.

IV. Neurological Examination

In this section is described a systematic method of examining the nervous system, stress being laid on the points which must always be looked for, and the manner in which the search should be carried out.

Examination of the Segmental Muscular Power

The search for paralyses.—The examination must be carried out on the patient when recumbent, and methodical tests made of the segmental muscular

[1] Pierre Marie, Foix, and Bertrand, "Recherches sur la topographie cranio-cérébrale, etc.," *Société de Neurologie*, 2nd March 1916: *Revue Neurologique*, No. 3, March 1916, p. 437.

power of the limbs, trunk, and neck—that is, the power of flexion, extension, abduction, adduction, and rotation in each segment of the members must be tested. The procedure is as follows: The patient is told to flex the forearm on the arm, and, when this movement has been completed, to resist an attempt made by the observer to extend it. In this way the patient is made to put forth the maximum of effort required for each movement. It does not suffice to tell the patient to bend his elbow or to extend his leg, and then for the observer to resist the movement before the flexion of the elbow or the extension of the knee has been carried as far as possible, because, in this way, a wrong impression of a diminution in muscular energy might be received by the examiner.

The testing must be systematically carried out. In the upper limbs: Flexion and extension of the fingers, testing separately the flexion of the metacarpo-phalangeal joints (interossei); flexion of the second and third phalanges (flexors of the fingers). Extension of the first phalanx. Extension of the second and third phalanges. Abduction and adduction of the fingers. Abduction, adduction, and opposition of the thumb. Flexion, extension, and lateral movements of the wrist. Flexion and extension of the elbow. Pronation and supination of the forearm. Raising the arm to the horizontal forwards and laterally; raising it vertically. Adduction of the arm. Rotation of the arm inwards and outwards. Elevation of the shoulder.

The movements must be tested successively on the sound and on the affected side. In order to obtain a standard for comparison it will be necessary in certain cases to test the segmental muscular power simultaneously on both sides; for instance, flexion of the elbow or the abduction or adduction of the arm.

Similar tests are applied to the lower limbs under similar conditions—flexion, extension, adduction and abduction of the toes; flexion, extension, abduction and adduction of the foot; flexion and extension of the leg on the thigh, etc., as in the upper limb and under similar conditions.

Movements of the trunk.—The patient being seated and bent forward, he is pushed backwards with instructions to resist the movement, care being taken to fix his knees. Extension of the trunk is tested by reversing this procedure.

Movements of the head.—Flexion, extension, rotation, and lateral inclination will likewise be tested, care being taken in each case that the movement is completely carried out, and then opposing it. The examination will be concluded by testing the motility of the face: by putting out the tongue; opening the mouth; showing the teeth; whistling or blowing; laughing; shutting both eyes, then each eye separately; frowning and raising the eyebrows. During these movements observation should be made of the contractions of the platysma on each side, care being taken that the neck is completely uncovered, the head erect and not inclined too far backwards.

In the examination of the motility of the face are included the following:—

1. Test of the motility of the tongue (hypoglossal nerves), observing whether there is any atrophy or fibrillary tremors. 2. Test of the trigeminal nerve: closure of the jaws by contraction of the temporal and masseter muscles, lateral movements of the jaw by the pterygoids. By palpation the observer will be informed as to the condition of the masseter, and will be able to detect any more or less marked atrophy of the muscle.

Examination of the Reflexes

Reflexes of the bones and tendons.—The reflexes are tested by comparing them on the two sides of the body.

A. *Lower limbs.*—A beginning will be made with the *patellar reflexes.* The best method is to make the patient sit on a chair with the knees slightly bent, the feet resting flat on the ground, and to practise percussion on the tendon on the right and left sides alternately, after instructing the patient completely to relax the muscle. This relaxation is not always easy to obtain, and palpation of the quadriceps extensor cruris must be employed to ascertain whether this muscle is in complete relaxation. This method is much to be preferred to the method of testing the reflexes with the leg under examination crossed over the other, or with the legs hanging over the edge of the bed, or with the patient recumbent. Reflex centre, 3rd lumbar segment.

If the reflex is very feeble or imperceptible, test it by Jendrassik's method, the patient straining on the crooked and interlocked fingers of the two hands while percussion is applied.

The Achilles reflex.—The patient kneels on a low chair and percussion is applied to the tendo Achillis, after seeing that the foot is not fixed by muscular contraction. If no reflex is perceptible, it is advisable to make sure by direct percussion over the belly of the triceps suralis that idiomuscular contraction is present, and that the absence of a tendon reflex is not due to a defect in the technique employed to elicit it. A similar control test should be applied to each one of the tendon reflexes. While the patient is in this position he can be tested for the medio-plantar reflex (Guillain and Barré) by percussion of the median portion of the sole, when the same reflex

action should be obtained as by percussion of the tendo Achillis. Reflex centre, 1st sacral segment.

B. *Upper limbs.—Reflex of the triceps brachialis* or of extension of the forearm. The examiner seats himself beside the patient, who is made to carry his arm outwards and backwards, and to place his hand flat on his thigh. Percussion is then made over the tendon of the triceps near the olecranon, and note is made of the muscular shock in the triceps. Reflex centre, 7th cervical segment.

The forearm flexion reflex or *the lower radial reflex.*—This is elicited by percussing the lower end of the radius, the elbow being partially flexed and the forearm in semi-pronation and supported by the observer's left hand; the percussion should give rise to flexion of the forearm on the upper arm and a flexion of the fingers. Reflex centre, 5th and 8th cervical segments.

The ulnar pronation reflex.—While the patient is in the same position as before, percussion is made over the postero-inferior portion of the ulna; this should give rise to pronation of the forearm and slight flexion of the fingers. Reflex centre, 6th cervical segment.

These are the five tendon and bone reflexes which it is essential to test. In particular cases it is advisable to test some others, such as the acromial, subspinous, clavicular, masseteric, etc., which will be indicated when required. In every case it is absolutely necessary when testing the reflexes to remember that the patient must be in complete muscular relaxation, that the test must be made meticulously by comparing one side with the other, and that it must never be decided that a reflex is absent until after a prolonged and minute examination under the best possible conditions. Normally the reflexes, whether strong or feeble, are equal on the two sides; it is the absence

or the dissimilarity of the tendon reflexes which is of special pathological significance.

Cutaneous and mucous reflexes.—The following cutaneous and mucous reflexes should always be tested:—

Plantar cutaneous reflex.—This reflex is of the greatest semeiological value. In making the test it is most important that the muscles of the leg and thigh shall not be contracted; the leg should be slightly bent on the thigh and supported by the observer. If the sole of the foot is then excited by passing a pin along its outer border from the heel to the base of the toes there will be produced, normally, a reflex movement of flexion of the toes, or the toes may remain immobile. If there is a lesion of the pyramidal tract, tickling the sole causes extension of the toes, especially of the great toe, abduction of the toes (the fan), contraction of the tensor fasciæ femoris, and sometimes flexion of the leg on the thigh. The stimulus necessary to produce this reflex is sometimes strong and sometimes slight, and must be applied alternately to the skin over the inner and outer half of the sole respectively. There are cases in which excitation of the inner half of the sole gives rise to flexion of the toes, while that of the outer half gives rise to extension only.

By repeating the test several times in different positions, and with varying degrees of excitation, while observing the other reflex movements associated with extension of the toes, all sources of error will be eliminated. In some cases reflex extension of the great toe may be produced by slight excitation of the skin of the dorsum of the instep, or of some point on the skin of the lower limb.

Another very important plantar cutaneous reflex on which great stress has rightly been laid by Hirschberg, and more recently by MM. Pierre Marie and Meige, is the *adductor reflex of the foot.*

As in the last case, the test is carried out with the patient seated, or flat on his back with his legs projecting beyond the end of the bed, or on his stomach with both legs raised nearly to a right angle with the thighs. Having ascertained that there is no muscular contraction, the skin of the inner border of the foot is scratched by drawing a pin or bodkin from the base of the great toe to the heel. A reflex adduction of the foot is thus induced by contraction of the tibialis posticus; the foot is adducted, and the sole inverted with elevation of its internal border. In many wounded subjects it is difficult to get a response from the great toe by tickling the sole, while adduction of the foot is easily produced. This reflex is most important as indicating very slight lesions of the pyramidal tract, especially in the cortical region, at the level of the motor centres for the lower limb.

Cremasteric reflex.—This is obtained by excitation of the skin of the inner aspect of the thigh, and shows itself by a sudden raising of the testicle on the side tested through the contraction of the cremaster. This reflex must not be confused with the slow, vermicular, much more lingering contraction produced under the same conditions by contraction of the involuntary muscle of the dartos (scrotal reflex).

Abdominal cutaneous reflex.—This may be divided into three groups: upper, middle, and lower. Rapid excitation, upwards, with a bodkin of the skin of the abdomen, at the level of, or below, the umbilicus to one side of the median line, produces reflex contraction of the subjacent muscles. Here also it is necessary to make sure that the abdominal muscles are completely relaxed.

Palate reflex.—The velum palati is lightly touched with a twist of paper to right and left of the median line; a reflex elevation of the velum is produced, which must not be confused with the reflex of nausea.

The corneal reflex.—The cornea is touched lightly with a hair, care being taken not to brush the eyelashes; an instant closing of the eyelids is induced.

Automatic spinal reflexes (Pierre Marie and Foix) or *defensive reflexes.*—These are complex, co-ordinated, reflex movements, which are provoked by excitation of the deep or of the superficial sensibility, and arise from automatic action of the cord.

We shall describe only the phenomenon of retraction, which are the most frequently observed and the most important of these reflexes.

This consists essentially of a movement of retraction of the lower limb, which is evoked in the following manner: The patient is extended on the bed and in complete muscular relaxation, and his toes are grasped by the observer and progressively and forcibly flexed. This induces a movement of retraction of the entire lower limb, first of the foot towards the leg, then of the leg towards the thigh, and then of the thigh towards the pelvis, the movement being quite involuntary. This reflex may also be obtained by superficial cutaneous excitation by pinching the skin of the foot or the leg (test for plantar cutaneous reflex).

These reflexes are very frequently met with in the course of spasmodic affections of the nervous centres, and especially when there is more or less complete interruption of the conduction paths between the brain and the spinal cord.

Clonus.—*Ankle clonus* or epileptiform tremor of the foot is tested for by raising with the left hand the patient's leg, which must be in complete muscular relaxation, and with the right hand sharply dorsiflexing the foot without letting go of the leg. This produces a rapid, regular, and rhythmic series of movements of flexion and extension of the foot. This epileptiform tremor is sometimes elicited in testing for the patellar reflex.

This truly pathological clonus must not be confused with the false clonus (Babinski), which can be produced by voluntary contraction of the muscles, but this latter is neither so prolonged nor so regular as the true clonus, and is not in the least pathological.

Patellar clonus is produced by pushing the patella sharply downwards, and thus causing oscillations of it by rhythmical contractions of the quadriceps.

The various types of clonus are indications of exaggerated reflex activity (Babinski).

Examination of Sensation

Superficial sensitiveness.—The patient is laid on the bed, completely uncovered and blindfolded. This examination should be carried out in a well-warmed room, otherwise the patient is liable to shiver and have vasomotor alterations, and therefore to return vague answers.

Tactile sensation.—The patient must be told exactly what is going to be done ; thus : " I am going to touch you lightly with my finger (or with a brush or pencil), and you must tell me, ' I feel,' or you will count, 'one, two, three, etc.,' each time you feel anything." It is generally necessary to make two or three trials, so as to be quite sure that the patient fully understands, before starting the examination. In this way the tactile sensation is tested, care being taken to proceed from one spot to another at random, and lengthening or shortening the intervals between successive contacts. The observer must merely touch, not press or rub, and every now and then should ask the patient to put his finger on the spot touched (sense of localisation), taking note of any error in doing so. The testing of the facial sensation must not be overlooked, particularly in the trigeminal area, for which purpose it is better to use a tuft of cotton-wool or a hair.

If the examination shows modification of sensation in any particular region the zone of the anæsthesia or

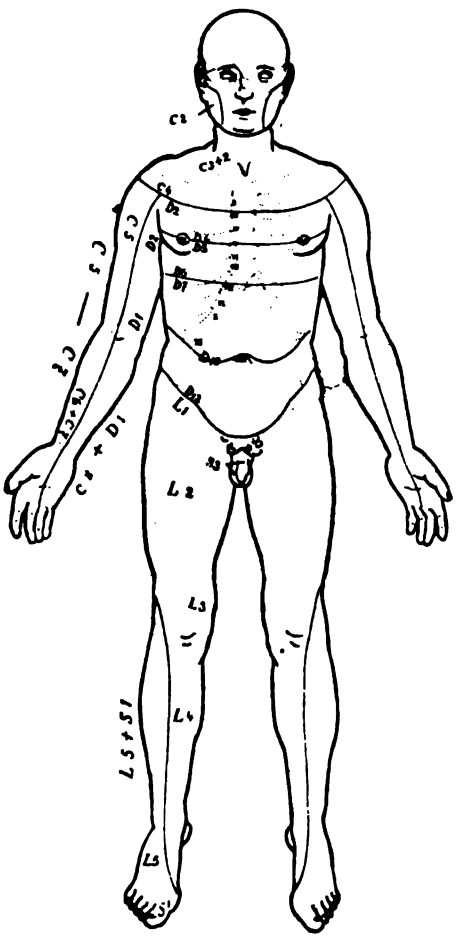


FIG. 5.—Diagram of the radicular topography of sensation. (The letters with index figures indicate the nerve roots and the corresponding spinal segments.) Front view.

hypoæsthesia must be carefully and minutely tested, and its extent mapped out by proceeding from the normal towards the affected region, and *vice versa*.

The first method generally shows a slightly smaller anæsthetic zone than the other. In certain cases

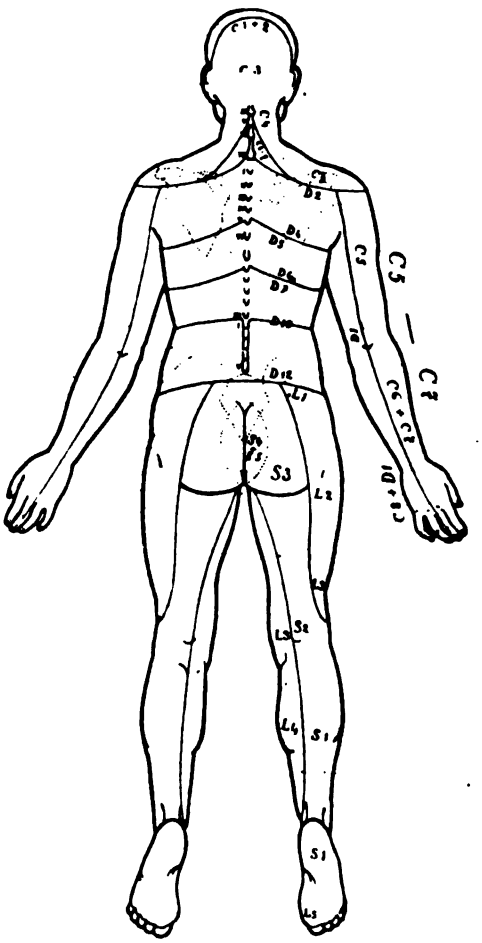


FIG. 5A.—Diagram of the radicular topography of sensation. (The letters with index figures indicate the nerve roots and the corresponding spinal segments.) Back view.

Weber's compasses may be used to see how far they must be opened before a double contact is no longer felt as a single one (tactile discrimination).

Sensibility to pain—thermic sensibility.—The patient remaining under the same conditions, the first of these tests is made with a pin, observing whether there are any zones of hyperalgesia. The thermic sensibility is tested by using two large test-tubes, one filled with hot water at 50° C. (124° F.) and the other with cold. The patient is to say whether what he feels is hot, or cold, or neither.

Deep sensitiveness.—Whether there are any disorders of the superficial sensitiveness or not, examination of the deep sensitiveness must never be neglected, as it is of great importance. The following tests should be carried out :—

Osseous sensitiveness to the tuning-fork.—A powerful tuning-fork is struck, and, while it is vibrating, its stem is applied to various superficial bony points, *e.g.* the malleoli, the articular ends of the long bones, etc.

Sense of segmental attitude, or *the sense of position.*—The limb under examination is placed in positions of increasing complexity, and the patient is told to reproduce the position with the other limb, or to describe the position in which the limb is.

Sense of passive movements.—Very slow movements of flexion and extension are practised on different parts of the various limbs, and the patient is told to state whether he can follow mentally the movement and the sensation of movement.

Stereognostic sense.—By this term is meant the faculty of recognising the nature of an object by palpation and touch while the eyes are closed. Various objects—a knife, pencil, key, watch, coin, button, pin, etc.—are successively put into one hand of the patient at a time, and he is then asked to say what it is. Each hand must be tested separately.

When the paralysis is too extensive for the patient to finger the object, he must be helped by bending his fingers and placing the object between the palm

and the pulp of the fingers. It is useful to test the stereognostic sense in both the radial and the ulnar halves of each hand separately. Some patients can identify an object between the thumb and the index finger, but not if it is placed between the two last fingers and the palm, or *vice versa*.

All the facts ascertained relative to the disorders of sensation should be recorded on one or more models of the type shown in figs. 5 and 5A.

Examination of Co-ordination

Lower limb.—While the patient is recumbent he is told to place the heel of one side on the knee of the other, to remain in this position for a moment, then to extend the leg, and repeat the movement four times. Observation must be made how this movement is performed: whether there are tremors while carrying it out; whether the heel can be kept steady on the knee; whether the movement is repeated regularly or at varying speeds, and with an exaggerated sweep of the limb (dysmetry). The patient should be made to go through the same movement with the eyes shut, and note made of any variations thus produced.

The following exercises may also be applied: Bring the heel up to the buttock, and put the foot flat on the bed; extend the leg to its full length, and repeat the movement.

If the patient is able to stand, let him stand upright in front of a low chair, lean with both hands on the back, place the front part of the sole of the foot on the edge of the chair, return the foot to the ground, and repeat the movement four times in succession with each foot, noting whether he catches his foot on the edge of the chair or raises it too high.

Upper limb.—The patient is told to put the tip of his index finger on the end of his nose, the arm being

each time extended to its full length; this is to be done first with the eyes open, and then with them shut.

Test of diadococinesia (Babinski).—The patient is made to execute movements of pronation and supination of the forearm in rapid succession with each arm separately, note being taken how the movement is performed.

Examination of Equilibrium

The patient is told to stand erect with his heels together, then with his feet and heels together, then to stand on each leg successively. Note will be made of the changes in equilibrium produced when the patient turns his head backwards, or turns it sharply to the right or to the left. The movements must be repeated with the eyes shut (Romberg's test). If the patient falls, note will be taken whether the direction is always the same, whether he falls in a mass, or makes irregular movements to regain his equilibrium. These simple tests will be supplemented, if possible, by labyrinthine tests, which are described later on.

Examination of the Gait

The gait often shows slight alterations which the tests of segmental power or co-ordination have not clearly disclosed. It must be made the subject of protracted study to define the disorders which may be ascertained: Titubation; lateral deviation; swaying forward; late repulsion; bending; stepping as if going up stairs; swinging the arms as in mowing; spasmodic gait, with very short steps; associated movements. It is impossible to exaggerate the importance of attentive study of this function, which must be completed by a study of ordinary walking.

This examination must be made with the patient completely undressed.

The detailed consideration of the disorders of co-ordination, equilibrium, and gait will be gone into in connection with wounds of the cerebellum, when it will be necessary to expand the various clinical tests which we have just described (see Chapter IX.). But in any case the above tests must always be carried out in the routine examination of a neurological injury.

Examination of the Speech

To this subject is devoted a chapter dealing specially with the technique of the examination of a patient suffering from disorders of the speech (Chapter VII.).

Examination of the Sensory Apparatus

Visual apparatus.—It is most necessary that the neurologist should be qualified to make a brief test of the visual functions of the patient whom he is examining. The following are the investigations which it is most important for him to carry out :—

1. *Test of the ocular movements.*—The first thing to note is whether there is any strabismus. The patient is then told to follow the observer's finger with one eye, the other being closed, and then with both eyes, the head remaining immobile. Note is made whether the movement of the eye is complete in every direction, and if there is any sign of nystagmus (horizontal, vertical, or rotary), that is, of rhythmic ocular vibrations. The vibration of nystagmus includes both a rapid movement and a slow movement in the opposite direction ; it is the direction of the rapid movement which stamps the character of the nystagmus.

The patient is asked if he always sees one or two fingers during the test. If there is diplopia, the test

is made more definite by making the patient put a piece of red glass before one eye, and, under the same conditions as before, he is told to follow the flame of a lighted candle with his eyes. If he sees two flames, one red and the other white, he is told to describe their relative positions, by which test it will be possible to ascertain the muscle whose paralysis is the cause of the diplopia.

Examination of the pupil.—This examination should be carried out in the dark room by artificial light. Observation is made of the shape and size of the pupil; of inequality of the pupils; the pupil reflex to light both direct and consensual, that is, by observing one pupil while the light is thrown on to the other. The test is completed by testing the pupil reflex for both convergence and accommodation.

Visual acuity.—This test must never be neglected, but before carrying it out it is first necessary to correct any error of refraction. The patient is then placed at a distance of 5 metres (16¼ feet) from a sheet of test types, the acuity being indicated by the figure opposite the line of the smallest characters which he can read.

Examination of the ocular media and the fundus oculi.—The examination will be concluded by a test of the ocular media (the cornea, the anterior chamber, and the lens) with a plane mirror or by oblique light, and then of the fundus (the disc and the macula) indirectly by the reversed image, or directly, if necessary, after dilatation of the pupil by homatropin.

The technique of examination by the perimeter will be found in Chapter VIII.

In many cases it will not be possible to carry out the examination in such detail, and then a specialist must be called in; but every neurologist should be qualified to carry out this elementary examination, if only to get a fair idea of the lesions, and to send

the patient to the specialist with some information on the case.

Auditory apparatus.—The same thing may be said with regard to examination of the auditory apparatus, at least as far as auditory tests are concerned. As regards the vestibular tests, they concern the neurologist as much as the aurist, and he ought to know the technique. Information will be obtained as to the condition of the hearing by bringing a watch near to the auricle and noting at what distance the ticking can be heard; or by pronouncing in a whisper various numbers (12, 22, 33, 40, 55, 66, 70, etc.) which the patient has to repeat, and measuring the distance at which the words are audible to the patient.

Tests with the tuning-fork.—Only an otologist can make a more exact measurement of the auditory acuity, but for the neurologist it is necessary to locate precisely the anatomical site of the lesion by the following tests :—

Schwabach's test.—Apply the end of a low-pitched tuning-fork in vibration to the mastoid, and note how long it is heard. (Prolongation of the perception indicates lesion of the apparatus of transmission; abbreviation, lesion of the apparatus of perception.)

Weber's test.—Place the vibrating fork on the top of the skull. (If there is a lesion of the apparatus of transmission on one side, the sound will appear louder on the same side; if there is a lesion of the apparatus of perception, it will appear louder on the other side.)

Rinne's test.—Apply the foot of the fork in vibration to the mastoid; when it can be no longer heard, the still vibrating prongs of the fork are brought near to the auditory meatus, when it is heard again for several seconds. (If the sound is no longer perceptible, the lesion is situated in the apparatus of transmission; Rinne's negative.)

Lombard's test.—If the patient suffers from unilateral deafness, the functioning of the sound ear is suppressed by injecting water into the auditory canal, and he is told to read aloud; the pitch of his voice will be considerably increased during the experiment if the deafness is of central labyrinthine origin (apparatus of perception).

By these tests it can be ascertained whether the site of the lesion is located in the apparatus of transmission or of perception. If the results obtained are abnormal, the case must be referred to an aurist.

Vestibular tests.—The tests which concern the vestibular portion of the labyrinth are much more important to the neurologist, because they supply valuable information regarding the functions of the cerebellum, as well as of the condition of the labyrinth itself.

Before applying them the patient must be questioned as to any subjective disorders from which he may be suffering—vertigo, sense of falling or tottering, or displacement of objects, etc.—and note must be carefully taken, by means of the tests already described, whether there is spontaneous nystagmus or static or kinetic disturbance of equilibrium.

Then the following tests will be made: Rotation test, Barany's caloric test, and Babinski's voltaic vertigo test.

Rotation test.—The simplest plan is to seat the patient on a revolving chair with his head erect and his eyes closed. The chair is rotated from left to right twelve times in about thirty seconds. Under normal conditions, when the rotation is stopped there will be horizontal nystagmus to the left, lasting for about half a minute. If the patient's equilibrium is tested, the body will tend to fall to the right, but this will vary according to the position of the head.

After a few minutes the test is repeated by rotating the chair in the opposite direction the nystagmus

will then be to the right, and the inclination to fall to the left.

This test is inconclusive, inasmuch as its effect varies greatly in different subjects; it is not sufficiently sensitive, and as the excitation affects both labyrinths at the same time, it is impossible to get accurate results regarding one only. Rotation to the right specially affects the left labyrinth, and *vice versa*.

The pathological modifications observed in the course of these tests will be stated when dealing with lesions of the labyrinth.

Barany's caloric test.—This test is carried out by injecting hot or cold water into the auditory canal at a moderate pressure. We shall confine our attention to the cold-water test, as it is the most rapid and the most certain; but before carrying it out, the condition of the ear must be examined to make sure that the canal is not obstructed by wax. If the tympanum is perforated, the injection should not be made.

If all is well, the procedure is as follows: Water at a temperature of 25° C. (79° F.) is injected from an ear nozzle into the auditory canal by means of a glass irrigator placed about 20 inches above the level of the canal while the patient is seated with the head upright or inclined slightly backwards; he is told to look away from the injected ear, and his eyes are observed while the injection is being made.

Under normal conditions the following phenomena will be observed: 1. In half a minute to a minute there will be lateral nystagmus to the side opposite to the injected ear, at first slight, but becoming very intense. 2. The injection is stopped, and the patient is placed erect, with his feet together and his eyes shut; there will be a tendency for the whole body to fall to the side corresponding to the ear injected. If the patient's head is now turned 90° to that side, so that the ear is directed backwards, the inclination will be

backwards. If his head is then turned 90° to the opposite side, so that the injected ear is directed forwards, the inclination will be forwards. All these reactions are labyrinthine in character, but vary greatly in intensity in different subjects. 3. In the course of this test there will be found involuntary movements of the limbs, provoked by the cerebellum under the influence of the stimulation of the labyrinth. For instance, if a normal subject is told to shut his eyes and hold out his arms in front of him, he will easily maintain this attitude for some minutes. But if a right lateral nystagmus is produced in the same subject by injecting cold water into his left ear, and he is told to assume the position, his arms will be seen to deviate slowly and insensibly to the left. In a recumbent subject the same results will be obtained in the lower limbs.

All these labyrinthine reactions obtained by the caloric test are accompanied by more or less marked subjective disturbances—vertigo, nausea, etc. Their intensity varies greatly in different subjects, and the tests should be repeated several times.

This chapter deals only with the technique of the normal reactions, their pathological modifications being reserved for another chapter, in which we shall enter into full details of the modification of the involuntary movements, which are of the highest importance in the localisation of wounds of the cerebellum (Chapter IX.).

Voltaic vertigo test (Babinski).—If the poles of a galvanic battery are applied in front of the tragus on both sides of a normal subject and a current of 2 to 5 milliampères is passed, the head is inclined towards the side of the positive pole. The battery should be of twenty-four elements, connected in series, and provided with a rheostat and a milliampèremeter. The electrodes should be pads, about 1 inch in

diameter, which the operator keeps moistened and firmly applied in front of the tragus on each side, the patient being erect with his feet together when the current is turned on. With a current of 1 or 2 milliampères in a normal subject the head inclines to the side of the positive pole, and if the current is increased, the whole body is drawn to the same side, and with this is often associated a rotary nystagmus directed to the negative pole. If the current is suddenly cut off, the head returns to its normal position. This test is accompanied by more or less marked sensations of vertigo. The voltaic vertigo is sometimes produced by a very weak current, but in some cases the resistance to the voltaic vertigo is exaggerated, and the current has to be increased to 15 or 20 milliampères to induce the inclination of the head. The characters of the nystagmus vary greatly, and in healthy subjects it may be absent.

The pathological modifications of the voltaic vertigo (which will be dealt with later on) frequently resemble those of Barany's caloric test, but there is not necessarily any connection between them. With this test, as with Barany's, involuntary movements of the limbs may be observed.

Lumbar Puncture. Radiography

The description of the neurological examination of a patient suffering from a wound of the skull will be concluded by a brief analysis of two complementary procedures which are very important in diagnosis.

1. **Lumbar puncture.**— As the technique of this operation is well known, it will not be necessary to describe it in detail; it will suffice to state the following points:—

The fluid must always be tested for excess of albumen by adding nitric acid, drop by drop, to a

known quantity of the cold fluid, shaking it meanwhile until the opalescence ceases to increase. After a little practice the quantity of albumen per litre can be fairly accurately estimated. The normal proportion is about 0·20 centigram per litre. Much greater exactitude can be obtained by using the graduated tube introduced by MM. Sicard and Cantaloube. To 4 cubic centimetres of the slightly warmed fluid are added 12 drops of trichloracetic acid solution (1 in 3); the fluid is allowed to stand for four hours, and the height to which the precipitate has risen on the scale is noted. The quantity of albumen per litre corresponding to the division reached can be ascertained by reference to a table prepared by the inventors.

The cytological examination is both qualitative and quantitative. *Quantitative test.*—Nageotte's cell is used, and, by a procedure precisely analogous to that employed in a blood-count, the proportion of cellular elements per cubic centimetre of the cerebro-spinal fluid can be ascertained. For the qualitative analysis, 10 cubic centimetres of the cerebro-spinal fluid are centrifugalised for thirty minutes; the sediment is collected, and a slide is prepared; after fixation and staining, the cellular elements are examined with an immersion lens.

There are two definite indications for lumbar puncture, which will be dealt with later on; one, cases of head-wounds which present no objective sign of cerebral lesions and yet complain of subjective disorders; and the other, when a complication, such as meningitis, abscess, or encephalitis, is feared.

2. **Radiography.**—This is one of the most essential points in the examination of a wound of the skull, and it is important to observe certain rules of procedure which M. Infroit of the Salpêtrière has long urged.

The usual method is to radiograph the subject lying

flat on his belly, with the right or left side of the face on the radiographic plate. This method has many disadvantages; the varying inclination of the head towards the chest and laterally causes considerable distortion of the bony outlines, and renders the interpretation of the radiograph unreliable. To carry out the system suggested above of cranio-cerebral topography based on fixed datum-points, it is necessary to ensure both the complete immobility of the subject and that the position of the head shall always be absolutely identical. The technique, which is too complex to be described in detail, has been worked out by M. Infroit, the head of the Radiographic Laboratory of the Salpêtrière.

Radiographs taken full-face and in profile show the site and dimensions of the bone defect, the line of a fissured fracture, the presence of fragments, or of any foreign metallic body; by comparison of the various plates, the site of these can be ascertained with great accuracy.

CHAPTER II

THE SUBJECTIVE SYMPTOMS COMMON TO ALL SKULL WOUNDS

The Ordinary Subjective Syndrome

IN nearly every case of wound of the skull the patient complains of purely subjective disorders, the explanation of which is frequently extremely difficult. These subjective symptoms are to be found not only in cases in which there has been previously, or still is at the time of the examination, indisputable evidence of organic lesion of the nervous system, but even more frequently perhaps in cases in which the most minute neurological examination has failed to reveal the slightest organic symptom: no variation of the tendon or cutaneous reflexes, no aphasic symptoms, no disturbance of sensibility, and especially no trace of astereognosis, deficiency of the field of vision, or disturbance of equilibrium.

These subjective disorders occur in cases of wounds of the skull with astonishing regularity; their various types have been carefully studied in detail by M. Pierre Marie.[1]

HEADACHE

Nearly all the patients who have sustained a wound of the skull suffer from some form of headache. They complain of a feeling of pressure, constriction, and

[1] Pierre Marie, "La conduite à tenir vis-à-vis des blessurés du crâne," *Société de Neurologie*, 2nd March 1910.

throbbing all over the head, or in the frontal or the occipital region, and sometimes behind the eyes, extending on to the face. The seat of the headache is often different from the site of the wound, but the headache is always predominantly in either the frontal or the occipital region. Over the scar, whatever may be its characteristics, and in a fairly wide zone around it, there is frequently hyperæsthesia on the slightest touch; this is particularly marked over the cutaneous scar.

The headache is seldom continuous, but generally recurs at regular periods—on awaking in the morning, or on going to bed at night, or before meals, and is induced or increased by a number of circumstances. In the interrogatories of a large number of patients, the following are given as causes of aggravation of the headache: The act of stooping, sneezing or coughing; any physical exertion; walking rather quickly, going upstairs; even mental exertion, as reading or composing a letter; a rather strong light; bright sunshine, or the light of an arc-lamp. The headache is quickly induced by the sight of objects in motion, such as the wheels of a moving coach, or by looking at a cinema film, and it is then frequently accompanied by a sensation of vertigo, which will be dealt with below. Sudden shocks and loud noises, especially reports and explosions, are certain to bring on the headache, which is often associated with hyperacousis. Travelling on the railway (especially underground) or in a tram is very badly borne. The headache is also increased by changes in the external temperature; cold, extreme heat or high wind, all alike tend to increase it.

Vertigo: Giddiness

The patient almost always complains of vertigo as well as headache. What the patient calls vertigo

generally starts with giddiness: a cloud spreads over the sight; he feels that he is losing his equilibrium, although he seldom actually falls down; he is obliged to stop and support himself or to sit down; then he regains composure, but for a short time he feels upset and good for nothing, with a feeling of instability and unsteadiness in his walk. The giddiness is not regular in its recurrence; in some cases it occurs several times a day, and in others only at long intervals. Sometimes it is confined to a mere disorder of vision, such as an appearance of muscæ volitantes, when the patient looks steadily at an object for a long time, or reads too long, and it is not accompanied by vertigo.

Other subjective disorders.—In addition to the headache and vertigo, which are the most frequent and most evident, the patient suffers from other nervous disorders, which vary in prominence in different subjects. Among these are *Insomnia:* either the patient cannot get to sleep, or he starts up in the night with nightmare. *Changes in character.* The patient displays greatly heightened irritability or emotion, accompanied by more or less marked *vasomotor phenomena*; fits of rage, reddening of the face, and sometimes epistaxis; he perspires on the least exertion and there is frequently tachycardia, which, however, is seldom persistent. *Defective memory.* The patient will forget what he has been doing during the day, or an errand on which he has been sent. Finally, fatigue will rapidly follow even slight mental effort, and the effort will cause return of the headache and vertigo.

General characters of the ordinary subjective syndrome.—Nearly all patients describe the disorders above set out in almost the same way and in the same words. This is an altogether special and very characteristic syndrome, but its pathogenic explanation is extremely difficult. It is interesting to observe that neither the site, the dimensions, nor the depth of the

wound has any apparent connection with the intensity or type of the headache or vertigo, and patients in whom only the scalp has been cut complain of the same headache and vertigo. These disorders are most frequently associated with splintering of the external table of the skull. On the other hand, it often happens that patients presenting extensive cranial fracture, accompanied by hemiplegia, paraplegia, etc., do not complain of these disorders, and it may be stated that, speaking generally, this syndrome is apparently much less commonly met with among officers than among the rank and file.

Differential Diagnosis and Examination for Objective Organic Signs

Under these circumstances the symptoms of which the patient complains should be most minutely analysed, and search should be made for the most trifling organic signs which may give a clue to the cause of the purely subjective symptoms. Care must be taken not to confuse the commonplace symptoms which we have just described with an important symptom which reveals a more or less serious organic lesion of the brain.

The characteristics of the headache are in general so marked as to render it impossible to mistake it for the headache associated with the onset of an attack of meningitis, or with a cerebral abscess, which is, moreover, accompanied by important organic symptoms, which there will be opportunity to describe later. The vertigo and giddiness may, nevertheless, give rise to serious mistakes, but a careful analysis of the symptoms met with will eliminate any chance of confusing this giddiness without falling with the series of indubitably organic disorders which we shall enumerate.

The trifling dizziness experienced by patients suffering from wounds of the skull must not be identified with the scotoma scintillans, accompanied by slight headache, which occurs in cases of wounds of the occipital lobe, and is, moreover, nearly always associated with absolute scotoma of the hemiopic type, often of very small dimensions, and frequently ignored by the patient, but arising from a lesion of the occipital visual area. Again this sensation of vertigo, accompanied by a condition of general discomfort, must not be taken for an attack of petit mal, which may, however, occur at the termination of a crisis of scotoma scintillans. This will show the importance of analysing the symptoms, and making the most minute examination of the field of vision.

This giddiness must likewise be distinguished from the true disorders of the labyrinth, which is often by no means easy. The vestibular functions must always be carefully examined, especially by the application of the voltaic vertigo test. If the vertiginous manifestations are of the trifling character associated with the syndrome with which we are dealing, the reaction to the galvanic current is generally only slightly modified. But, as M. Babinski has pointed out, in whatever part of the skull the site of the wound may be, it is possible that there may have been a perturbation of the labyrinth causing the vertigo of which the patient complains, and an objective examination will then disclose various modifications of the reaction, such as increased resistance to excitation by the current, movements of the head backwards and forwards instead of inclination to one side, etc. To sum up, a complete neurological investigation must be carried out on every patient who presents the syndrome of subjective symptoms which has just been analysed, and special attention must be paid to the apparatus of the two special senses, which may reveal slight

organic lesions, the symptoms of which must be thoroughly inquired into.

The visual apparatus.—A thorough examination of the fundus must be made, and will reveal the presence of any lesion due to increased intracranial pressure. The field of vision must also be examined for an unperceived scotoma.

The auditory apparatus.—The vestibular function must be tested, and this will sometimes enable the observer to ascertain the actual cause of the vertigo.

When circumstances permit, the cerebro-spinal fluid must always be examined. In many cases lumbar puncture discloses appreciable modifications of the fluid, which indicate organic lesion of the nervous system (Claude, Sicard). One may find an increase in the pressure of the cerebro-spinal fluid measured by the manometer, which seldom exceeds 50 cubic centimetres of water; there is, however, no fixed ratio between the increase of pressure and the intensity of the subjective symptoms. There may also be an increase of albumen in the cerebro-spinal fluid, never considerable, and varying from 30 to 60 centigrams per litre (Sicard).

The use of radiography must never be neglected, as it may disclose the presence of fragments in the neighbourhood of a bone defect, or of a fissured fracture, or even of a missile in the brain that has been overlooked.

Course and Treatment

It is very difficult to make an exact prognosis in these cases. They make no perceptible progress, or progress very slowly. Cases have been known where the patient still complained of the same symptoms after several months. In particular, it may be stated here that several patients, who had undergone plastic

operations upon the bone defect on account of the severity of their symptoms, seem to have received no great benefit thereby.

The best *treatment* for a patient suffering from these subjective disorders appears to be to let him rest by giving him one, two, or three months' convalescent leave, during which he should follow a course of electric treatment if he is near a suitable institution. Hydrotherapy does not seem to give good results. Then, according to his condition, put him on temporary half-pay, or pass him into the auxiliary service.

Speaking generally, no soldier who has sustained a wound of the skull should be sent back near to the firing line, or anywhere in the neighbourhood of gunfire or explosions.

When the patient has a large pulsating defect in the skull he should be invalided out of the service, except in very rare cases.

Pathogenesis

In a very large majority of cases the origin of these subjective disorders must be sought in an organic modification of the nervous system, which, if not manifested by local indications, can be detected by these general indications. The results obtained by lumbar puncture will afford one test. As Professor Pierre Marie states in his report, "All the subjects describe their symptoms in the same way and in the same words. It is quite certain that this is not a case of the repetition of a lesson which has been learnt."

It is only possible to speculate concerning the importance and anatomical nature of the causal lesion. but it is quite possible, as Léri maintained, that these subjective disorders are connected with meningeal adhesions. Examinations in the course of operations

and post-mortems which have been made in some cases support this view. Still it would seem that an important part must be assigned to lesions of the venous sinuses, and especially to the superior longitudinal sinus, at least when the wounds are situated on the median line of the skull, since any obstruction or modification of the circulation in the venous sinuses may cause an important alteration in the entire circulation of the brain. The possibility of a commotion of the labyrinth by the intensity of the shock inflicted on the skull by the impact of the missile must also be taken into consideration.

CHAPTER III

WOUNDS OF THE FRONTAL LOBE

Anatomy

THE frontal lobe is that portion of the hemisphere which is situated in front of the fissure of Rolando. This lobe corresponds to the frontal bone, of which it occupies not only the squamous vertical portion, but also the whole of the orbital aspect. Its outer and posterior limits pass considerably beyond the margins of this bone. It is made up of four convolutions; one parallel to the fissure of Rolando, which is the ascending frontal convolution, and three horizontal convolutions, which are named from above downwards the first, second, and third frontal. Each of these joins the ascending frontal convolution at right angles, runs a course parallel to the upper convex border of the hemisphere, and, at the frontal pole, bends down to the under or orbital aspect of the lobe. Each convolution, therefore has both a superior or external and an inferior or sub-frontal portion. The first frontal convolution has also an internal surface.

The ascending frontal convolution is dealt with in Chapter IV. This convolution is divided from the three horizontal convolutions by the pre-rolandic, or pre-central, fissure, which runs parallel to the fissure of Rolando, and is often divided into two parts by

the junction of the posterior end of the second frontal with the ascending frontal convolution.

The first or superior frontal convolution is situated at the sagittal border of the hemisphere, and comprises an external or dorsal portion, which joins the

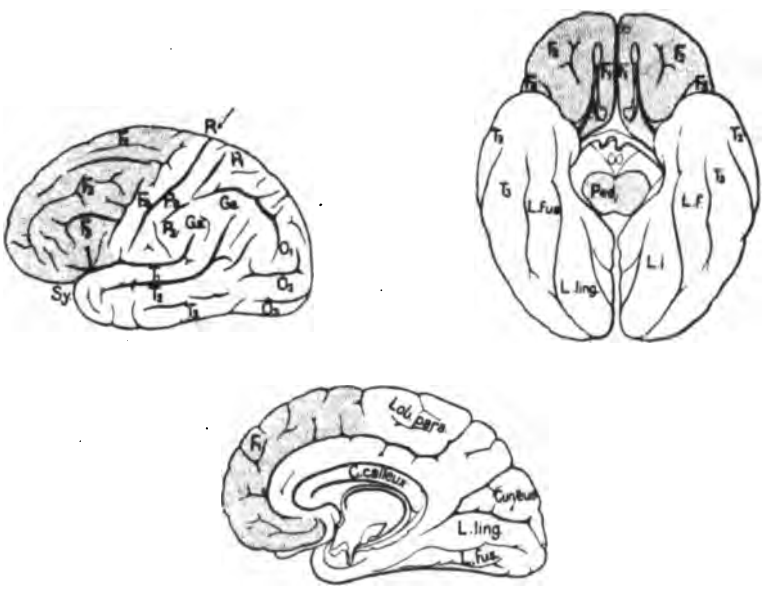


FIG. 6.—External and internal aspects of one hemisphere and inferior aspect of the brain.

The convolutions are marked by a letter with an indicator: F_1, first frontal; Fa, ascending frontal, etc.; Gs, gyrus supramarginalis; Ga, gyrus angularis; R, fissure of Rolando; Sy, Sylvian fissure; Lob. para, paracentral lobule; L. ling, lingual lobule; L. fus, fusiform lobule, etc.

ascending frontal convolution by three limbs, and is directed forward, becoming gradually thinner; a narrow, rectilinear, sub-frontal, or orbital portion, and an internal portion which occupies all that part of the internal aspect of the hemisphere above the convolution of the corpus callosum (callosal gyrus). The first frontal sulcus divides the first from the second

frontal convolution on the external aspect of the lobe. The orbital aspect of the sulcus is named the olfactory sulcus, and contains the peduncle of the olfactory bulb.

The second, or middle frontal, gyrus comes from the middle part of the ascending frontal. It is the widest of the three convolutions, and is much spread out and sinuous, occupying two-thirds of the orbital aspect of the lobe, and ends at the transverse branch of the H-shaped transverse orbital sulcus in the middle of the orbital aspect. It is divided from the third frontal convolution by the second frontal and the external orbital sulcus.

The third, or inferior, frontal convolution (also called Broca's convolution) lies between the second frontal sulcus and the Sylvian fissure. It is divided into three parts by the branches of the Sylvian fissure: the foot, the opercular portion, between the pre-rolandic sulcus and the ascending branch of the Sylvian fissure; the prominence, the triangular part between the ascending and horizontal branches; and the head, the orbital portion, which forms the posterior and external part of the orbital aspect. The white matter of the frontal lobe is made up of numerous association fibres: fibres of intrinsic association, arcuate fibres, occipito-frontal and uncinate fasciculi, and the callosal fibres.

It is not necessary to enlarge on the numerous varieties of cell-structure in the frontal region. The frontal type is characterised mainly by slightly marked development of the various cellular strata, and a deficiency in cellular elements.

Physiology

Medical men and psychologists have always devoted much attention to the functions of the frontal lobe, but in spite of the great number of physiological experiments and anatomical and clinical investiga-

tions which have been carried out, it may be said that we know little or nothing about its functions.

A. Physiological experiments have been carried out principally by two methods: electrical stimulation of the cortex, and total or partial extirpation of the frontal lobes.

The theory has long been maintained that the frontal lobes are a very important centre of association and the seat of the highest psychic functions. This purely theoretical assumption, which was based on the increase in size of the frontal lobes in the animal series in proportion as it approximated to man, has never received the slightest experimental confirmation. On the other hand, Munk and Sherrington appear to have shown by electrical stimulation of the frontal lobes that these do play a certain part in the motor functions. (It must be remembered that the ascending frontal is not included in this chapter.) Munk found in the dog a zone of excitability for the muscular system of the trunk and abdomen, and also for the respiratory movements. Sherrington could find in the monkey only one centre, of lateral movement of the eyeballs to the side opposite to the excited hemisphere, in the whole of the frontal lobe (exclusive of the ascending frontal gyrus). Extirpation of the anterior portion of the frontal lobe in the dog and the monkey has given no reliable result, although Munk appears to have observed a paralysis of the muscles of the trunk.

B. Human pathology, and especially the clinical study of tumours of the frontal lobe, has shown the existence of a certain number of symptoms, which some authorities consider characteristic of a frontal localisation. As the result of my personal experience, I have come to the conclusion that, in most cases, it is very difficult to say whether the symptoms are caused by a frontal lesion, or are due to the tumour acting on regions of the brain at a distance.

1. *Psychic symptoms.*—Important lesions of the frontal lobes are frequently accompanied by profound disorders of intelligence, etc.; a marked tendency to "joviality" on the part of the patient, who jests and indulges in witticisms which are often extremely puerile, has been held to be of pathognomonic significance, contrasting as it does with the slowness of his psychic reactions, the extreme diminution of his attention, and his apathy.

2. *Motor symptoms.*—Oppenheim has called attention to the existence of a permanent contracture of the muscles of the trunk in opisthotonos or emprosthotonos in the course of the development of tumours of the frontal lobe; this may also come on in crises. This approximates to the results of Munk's experiments. Conjugate deviation of the eyes to the side opposite to the lesion has also been noticed. Disorders of equilibrium and of co-ordination in the movements or the gait of patients who are the subjects of a tumour of the frontal lobe have been described under the name of frontal ataxia. These symptoms are by no means of regular occurrence, and many neurologists consider that they indicate action at a distance on the cerebellum. Motor disorders resembling the catatonic phenomena observed in cases of psychosis have been recently described by Kleist, who locates their cause in the frontal lobe (tonic innervation and tonic perseveration of Wilson). These symptoms will be considered under the head of apraxia. The disorders of speech observed in lesions of the left frontal lobe will be fully dealt with in the chapter on aphasia.

Symptoms

Site and characters of the wounds.—Attention must be given to some peculiarities of wounds of the frontal lobe.

A wound which involves only the frontal sinus must not be considered as a wound of the frontal lobe. The dimensions of the frontal sinus, whose cavity extends into the thickness of the frontal bone above the orbit, vary greatly in different individuals, its vertical diameter above the superciliary arch being often an inch or more. It is important to remember this, so as not to take what is really a wound of the frontal sinus for a wound of the frontal lobe, which is not to say that there may not be grave complications.

One striking circumstance which deserves examination is the relative frequency of very extensive injuries of the frontal region. It is usually in this region that the most extensive losses of substance are to be seen, gaps larger than a crown piece, with marked pulsation and impulse on coughing. It would seem from this that wounds of the frontal region are among the least grave, or, at any rate, the best borne; the vague symptoms of these wounds partly explains their relative benignity.

Symptoms.—It is hardly an exaggeration to say that there are no symptoms special to wounds of the frontal lobe. In the numerous cases which have been examined, the symptoms observed arose from complications peculiar to the wounds and not from the damage to the lobe itself. It may be said generally, however, that patients suffering from an important lesion of the frontal lobe present a peculiar mental condition, a kind of torpor and psychic numbness, slowness of ideation and speech, but in many cases the clinical examination shows no disorder definitely caused by the lesion of the frontal lobe (with the exception of the ascending frontal convolution). Except a slight alteration in the tendon reflexes, more marked on the side opposite to the wound (the lesion being in the neighbourhood of the motor convolutions), none of the symptoms enumerated above—contracture

of the trunk, deviation of the eyes, etc.—have ever been observed by us. account of the disorders of speech which on that wounds of the left frontal special mention, but these disorders in wounds of the right lobe, though not For instance, anarthria and dysarthria come on immediately after the wound, but for a few days or weeks, and have generally the time of the examination, the patient for some time he was unable to speak, very indistinctly, although he knew well what he wished to say. In other cases, of we have observed several, wherever any part of the left frontal lobe was involved, there hesitation or slowness of speech or stuttering stumbling that met with in disseminated sclerosis, which persisted for several months after the wound. On the other hand, there was no aphasia.

Complications peculiar to Wounds of the Frontal Region

1. **Facial paralysis.**—This is due to lesions of the superficial structures, and occurs even when there are no osseous lesions. It is caused by division of the branches of the superior ramus of the facial nerve, and is met with in lateral wounds of the temporal fossa far forward, and manifests itself by paralysis of the frontal muscle when it is of the partial peripheral type. In repose, the forehead on the wounded side is smooth and without wrinkles, and the eyebrow is flat. If the patient is told to frown, or to raise the eyebrows, the movement is absent on the paralysed side while on the other hand, the eye is usually easily shut. Electrical tests generally show loss of electric excitability of the frontal muscle, with total or partial R. D. This

paralysis must not be confused with total peripheral paralysis arising from a fissured fracture of the base affecting the facial nerve in the petrous bone, with which auditory troubles are often associated, nor with central paralysis, which, however, is generally on the side opposite to the wound.

2. Lesion of the frontal sinus.—When the wound is anterior and low down, that is, very near the upper edge of the orbit, the frontal sinus may be involved; in a number of cases, as has already been stated, it may even be the only part involved. If the posterior wall has been injured, and the dura mater or the brain brought into direct contact with the sinus, it is generally made evident by an escape of cerebro-spinal fluid from the nose, which may be very persistent, and recur intermittently for months, as has been observed in one case. This complication is particularly serious, because it exposes the patient to the risk of the formidable complication of meningeal infection; the subarachnoid cavity being placed in communication with a natural cavity may easily become infected even after the external wound has cicatrised.

3. Ocular lesions.—This is a very common complication in wounds of the frontal region and presents several important variations which it is important to know. It is always necessary to interrogate the patient as to the condition of the vision of each eye, to examine the fundus, especially the macular region, and to measure the field of vision and the visual acuity.

(1) *Lesions of the optic nerve.*— Immediately on receiving the slightest wound in the frontal region the patient loses the sight of the eye on the wounded side. The blindness is generally immediate and total, and it is only in rare cases that there remains even a vague perception of light. Examination of the ocular apparatus, and particularly of the fundus, does not

show anything abnormal at this time. The development is as follows: After a few weeks vision returns, but is much enfeebled; the patient is able to distinguish between light and darkness, but visual acuity remains very low, and the improvement does not increase; the power of vision may even disappear altogether. Examination of the fundus will show now a pallor of the disc, with narrowing of the vessels, indicating atrophy of the optic nerve. The pathogenesis of this atrophy is somewhat complex. It appears to be caused by extension of the fracture of the vault to the roof of the orbit and the optic foramen. The consequence is sometimes actual division of the optic nerve, but more frequently hæmorrhage into its sheath, with compression, and consequent atrophy, of the nerve.

(2) *Lesion of the oculo-motor nerves.*—Damage to the motor nerves of the eye as they pass into the orbit is much less frequently observed, though total or partial paralysis of the third, or the sixth nerve with strabismus or diplopia, may be seen, but these paralyses are not peculiar to wounds of the frontal region. The sixth nerve appears to be especially fragile, as a slight diplopia, arising from paresis of the external rectus muscle, which is innervated by this nerve, is observed in many patients wherever the site of the wound may be.

(3) *Lesions of the macula* are a very curious result of wounds of the frontal region, and sometimes of regions more distant from the eye. Immediately on receiving the wound the patient loses the sight of the eye on the wounded side. As his condition improves, vision returns in the peripheral portions of the field of vision, but only very slightly, and the visual acuity remains greatly reduced. In some cases the recovery is more complete, but the patient is left with a more or less extensive central scotoma, which

considerably limits the field of vision; its dimensions can be measured exactly with the perimeter. This scotoma, which is caused by an intra-ocular lesion, must not be confused with a macular or paramacular hemiopic scotoma caused by a lesion of the occipital lobe. The essential character of the latter is that it exists in both eyes, and is absolutely, or nearly absolutely, identical in both fields of vision. If there is a scotoma caused by ocular lesion, examination of the fundus will reveal the existence of very definite lesions of the macular region; sometimes simple œdema, sometimes hæmorrhage and lacerations in various stages of their development. This lesion is very interesting, because it is not due to a direct wound of the eye, but to damage at a distance by "contre-coup," as it were, the lesion being always confined to the macular region or its immediate neighbourhood.

(4) *Choroido-retinal lesions* are closely analogous to the foregoing as regards pathogenesis, and are marked by the same symptoms, but the modifications of vision are often more persistent, and perimetric examination shows the existence of a more or less extensive irregular scotoma, which is not confined to the macular region, and may not affect it at all: Examination of the fundus will show various lesions, often in the form of broad, straight, or stellate rents, whitish or edged with pigment, which are caused by actual rupture of the choroid, with consequent hæmorrhage.

Auditory lesions.—Unilateral deafness may exist on the wounded side, or even on the opposite side, or there may be bilateral diminution of the acuteness of hearing. Extension of the fracture to the petrous bone may be found (though seldom), when there will generally be total peripheral facial paralysis on the same side as the paralysis of the auditory nerve. Rupture of the tympanum or disorders of the

labyrinth caused by concussion at a distance are the most frequently found. There should always be a most careful examination for these auditory disorders.

Such are the complications of wounds of the frontal region. They are numerous and frequent, and, on the whole, much more important than lesions of the frontal lobe itself.

Diagnosis

It is evident from the above that the diagnosis of a direct lesion of the frontal lobe in cases of wounds of the frontal region will often be very difficult. The diagnosis must be based on the characters of the wound itself, the presence of a missile in the brain, and the accepted symptoms described above, which have hitherto been rarely observed except in cases of tumours of the frontal lobe; as already stated, the result of the examination will generally be negative. The examiner must always be careful to search systematically for indications as to whether the frontal sinus is involved, and for ocular lesions especially, and must make careful use of the ophthalmoscope to detect lesions of the macula, and of the perimeter for unilateral central scotoma.

Treatment

Wounds of the frontal lobe do not call for any special treatment; the ocular complications belong to the department of ophthalmology. When the loss of bone is extensive, there will always be a question as to whether there should be a plastic operation. When the loss of substance is plainly visible in the anterior frontal region, it may be desirable for the sake of the patient's appearance to cover in the

defect, but that is, in my opinion, the only valid reason. Plastic operations on the anterior wall of

FIG. 6A.—A wound on the left frontal region with very extensive loss of bone.

the frontal sinus appear to be well borne, and some of them have been perfect from the æsthetic point of view. The discussion of this very important question will be found in Chapter VI. of Part II.

CHAPTER IV

WOUNDS OF THE ROLANDIC AREA

Anatomy and Physiology

The Rolandic Convolutions

In the rolandic area are included the ascending frontal and the ascending parietal convolutions which surround the fissure of Rolando.

A careful study will be made here of:

1. The fissure of Rolando.

2. The ascending frontal convolution which forms the anterior lip of the fissure of Rolando, the three frontal convolutions coming off from its anterior border.

3. The ascending parietal convolution which forms the posterior lip of the fissure of Rolando, the superior and inferior parietal convolutions springing from its posterior border.

The situation and the anatomical and physiological importance of these two convolutions justify their being classed as a distinct cerebral region (the central lobe of Ecker) and being separated from their respective lobes.

The fissure of Rolando starts from the edge of the inter-hemispheric fissure, a little behind the middle of the hemisphere and is directed obliquely downwards and forwards, the obliquity increasing as the frontal

lobe becomes thicker, and terminates at a variable distance from the Sylvian fissure. In its course, which is not absolutely straight, it describes a superior curve which is convex in front, a median which is concave in front, and an inferior which is convex in front. The superior extremity forms a small notch on the internal aspect of the hemisphere, and is surrounded by the paracentral lobule, which unites the superior extremities of the two rolandic convolutions on the internal aspect of the hemisphere. The inferior extremity terminates above the Sylvian fissure, from which it is separated by the gyrus uniting the inferior convolutions of the frontal and parietal lobes, the rolandic operculum, sometimes very slightly marked, or placed very deeply in the Sylvian fissure. The floor of the fissure is nearly always intersected by deep transverse folds, forming deep annectant gyri, which intimately connect the two large rolandic convolutions which form the borders of the fissure.

The ascending frontal convolution begins on the internal aspect of the hemisphere, and is the largest part of the paracentral lobule. It runs obliquely downwards and forwards, following the curvatures of the fissures of Rolando, of which it forms the anterior lip. It terminates above the Sylvian fissure, passing round below the lower end of the fissure of Rolando to unite with the inferior extremity of the ascending parietal, thus forming the rolandic operculum.

The ascending parietal convolution also follows the curvatures of the fissure of Rolando, of which it forms the posterior lip. Its upper part is much narrower than the corresponding portion of the ascending frontal, with which its lower extremity is united above the Sylvian fissure by bending round the lower end of the fissure of Rolando. This bend forms the rolandic operculum, which covers the deep convolutions of the insula. The upper end of the convolution is bent

round the upper end of the fissure of Rolando, and unites with the upper end of the ascending frontal to form the paracentral lobule. The paracentral lobule is thus mainly made up of a thick frontal portion and a narrow and slender parietal portion. It will be

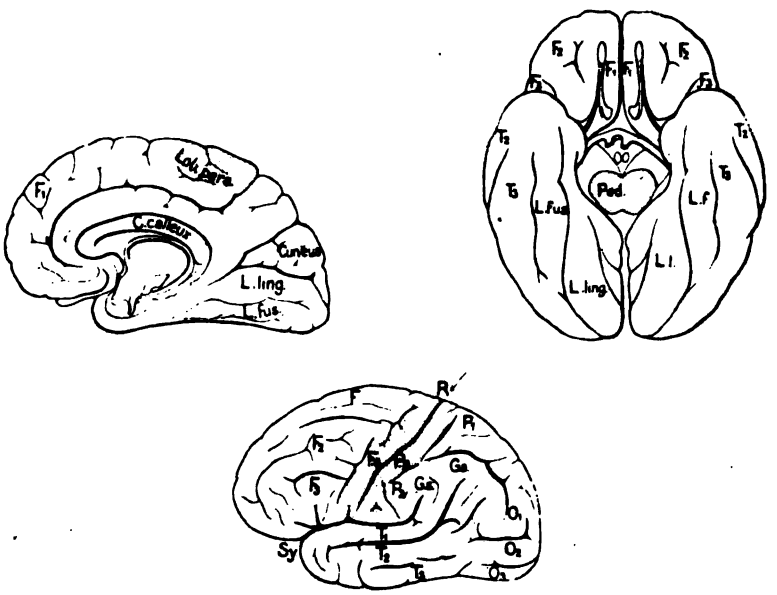


FIG. 7.—External and internal aspects of one hemisphere and inferior aspect of the brain.

The convolutions are marked by a letter with an indicator; F_1, first frontal; Fa, ascending frontal, etc.; Gs, gyrus supramarginalis; Ga, gyrus angularis; R, fissure of Rolando; Sy, Sylvian fissure; Lob. para, paracentral lobule; L. ling, lingual lobule; L. fus, fusiform lobule, etc.

evident that the ascending frontal and parietal convolutions form a true central lobe, which deserves to be studied apart from the respective lobes of which it forms part, because of its intimate union, its anatomical arrangement, and its physiological properties, which will be stated later.

Central motor and sensory tracts.—A whole system

of white fibres which form the central motor and sensory tracts is connected with the portion of the cerebral cortex that has just been described.

The central motor tract or centrifugal tract is formed of several sorts of fibres.

1. *The fasciculus geniculatus*, the fibres of which originate in the lower fourth of the ascending parietal and frontal convolutions and the rolandic operculum, and are directed transversely inwards across the centrum ovale in the middle segment of the corona radiata; they then form the genu of the internal capsule, passing out thence into the inner portion of the foot of the cerebral peduncle, and terminate in the pons and the medulla oblongata.

2. *The pyramidal tract* arises from the upper three-fourths of the ascending frontal and parietal convolutions and from the paracentral lobule. At their starting-point the fibres form a kind of fan placed transversely in the middle segment of the corona radiata and pass into the internal capsule, of which they occupy the posterior segment immediately behind the fasciculus geniculatus; they then pass into the foot of the middle cerebral peduncle. The whole length of the pyramidal tract thus formed passes through the ventral part of the pons, forms the anterior pyramid in the medulla oblongata, and divides into three groups of fibres at the inferior extremity of the latter structure; the most important of these groups, the crossed pyramidal tract, passes out in one mass to the opposite side; the second group, the direct pyramidal tract, descends in the spinal cord, and the fibres pass singly to the opposite side; the third group forms the homolateral fibres, which do not undergo decussation. All these fibres terminate in connection with the cells of the anterior cornua of the spinal cord.

The central sensory tract has two segments, an

inferior, the median band of Reil, which is a band of fibres which prolong the posterior column of the cord, and extend from the cells of the posterior cornua through the medulla oblongata to the inferior portion of the optic thalamus, and are joined by the sensory fibres from the nuclei of the cranial sensory nerves. The second or superior segment extends from the inferior portion of the optic thalamus to the cortex of the rolandic area, and on leaving the optic thalamus occupies the posterior segment of the internal capsule behind the genu, and is there intimately intermixed with the motor nerves of the pyramidal tract, described above. These fibres then pass straight into the centrum ovale, spread out fanwise in its median portion, and terminate in the two central convolutions, and particularly in the ascending parietal. It is important to state clearly the general arrangement of these white fibres, because wounds of the rolandic region are often deeply penetrating, and involve the white matter underlying the rolandic convolutions to a wide extent.

Histology.—Very important information as to the structure and cellular architecture of the rolandic cortex has been furnished by the researches of Brodmann and Campbell, a summary of which will be of interest.

The fissure of Rolando divides the rolandic region throughout its whole extent into two zones, which differ entirely in their cellular architecture. The anterior zone, which corresponds to the ascending frontal, is mainly characterised by the absence of the internal granular lamina and the presence of large pyramidal cells (cells of Betz), which increase in number in proportion as they come nearer to the paracentral lobule, disappearing altogether in the inferior portion of the ascending frontal. The posterior zone immediately behind the fissure of Rolando presents

various types of nearly similar structure, but no large pyramidal cells. It will be found that these cytological data have a very important bearing on the physiology of the rolandic region.

Physiology

Motor zone.—Before the researches of Sherrington it was supposed that the motor zone was situated in the ascending frontal and parietal convolutions and the paracentral lobule. The motor centres of all the muscular groups were supposed to be located around the fissure of Rolando; the centre for the muscles of the lower limb near the paracentral lobule, of the upper limb in the median portion of both convolutions; and the centres for the face, neck, and eyes in the inferior portion of the same convolutions. After laborious experiments on the ape, Sherrington and Grünbaum proved by means of unipolar faradisation that it is only in the ascending frontal and the anterior portion of the paracentral lobule that electrical stimulation of a given point produces a definite motor reaction. The motor zone therefore appears to be entirely pre-rolandic. These authors concluded their experiments with the destruction of very small portions of the cortex of the ascending frontal, thereby producing paralysis limited to a definite muscular group. A material contribution to the physiology of the motor convolutions has been made by Krause by a series of experiments on human beings. He made use of local electrical stimulation, and by this means located definitely the position of the motor centres in the ascending frontal, in front of the fissure of Rolando, to the exclusion of the ascending parietal. In other respects the distribution of the motor centres as stated by the older authors has been confirmed. They are so distributed that the motor centres of the lower limbs

are situated in the paracentral lobule and the superior portion of the ascending frontal, the centre for the arms in the median portion, and the centre for the face in the inferior portion of the same convolution. Without being so positive, Horsley reached similar conclusions, and was of the opinion that while the ascending frontal is mainly motor, it is also to a certain extent sensory, though much less so than the ascending parietal. It may therefore be said that, arguing from histological and experimental data, the ascending frontal, including the greater part of the paracentral lobe, is to be taken as the only motor zone.

Sensory zone.—The localisation of sensation in the cortex is at present not so advanced as is the case with the motor centres. Experiments on animals are very difficult to carry out, and their application to man is hardly justifiable. Experiments on human subjects have been carried out, but they are so few, and the results have been so uncertain, that no great reliance can be placed on them. The only data that are of any practical use are those furnished by clinical and anatomical observations. These show that, speaking generally, the sensory functions appear to be connected with the ascending parietal and the neighbouring regions of the parietal lobe, but that it is impossible to mark out more definitely the limits of the sensory area of the cortex. Efforts to locate the different forms of sensation—tactile, muscular, stereognostic, etc.—are quite uncertain and unreliable. The knowledge derived from experience with the wounded does not justify anything more than a general statement that sensory symptoms predominate, or are found alone, when the lesions are situated in the parietal region, and that motor symptoms are predominant, and a minimum of sensory disorders occurs, when the lesions are situated in the pre-rolandic region.

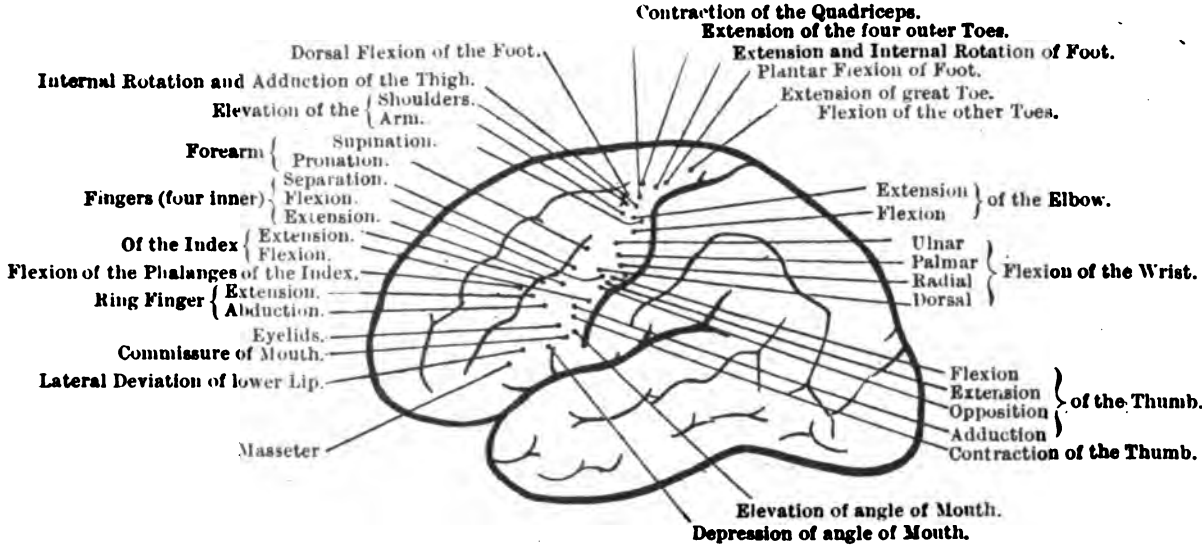

Contraction of the Quadriceps.
Extension of the four outer Toes.
Extension and Internal Rotation of Foot.
Plantar Flexion of Foot.
Extension of great Toe.
Flexion of the other Toes.
Dorsal Flexion of the Foot.
Internal Rotation and Adduction of the Thigh.
Elevation of the Shoulders. Arm.
Forearm Supination. Pronation.
Fingers (four inner) Separation. Flexion. Extension.
Of the Index Extension. Flexion.
Flexion of the Phalanges of the Index.
Ring Finger Extension. Abduction.
Eyelids.
Commissure of Mouth.
Lateral Deviation of lower Lip.
Masseter
Extension Flexion of the Elbow.
Ulnar Palmar Radial Dorsal Flexion of the Wrist.
Flexion Extension Opposition Adduction of the Thumb.
Contraction of the Thumb.
Elevation of angle of Mouth.
Depression of angle of Mouth.

FIG. 8.—Localisation of the cortical motor centres in the ascending frontal convolution in man, according to Krause, by the local electric stimulation method. It will be noticed that there are no motor centres in the ascending parietal convolution.

Physiology of the internal capsule: central motor and sensory tract.—Physiologists and clinicians have long been endeavouring to localise the various fibres which arise from the cortex, or travel to it, in the internal capsule.

(*a*) With reference to the paths of the various fibres of the motor tract, the supporters of the accepted view suppose that the cranial motor fibres (geniculate tract) are in the neighbourhood of the genu of the capsule; and the pyramidal tract properly so called divided from front to back into several zones (the cortico-cervical, brachial, lumbar, and crural), in the posterior segment; in short, the higher up in the rolandic zone the point from which the nervous fibres originate in the motor cortex, the further are they situated behind the genu in the posterior segment of the internal capsule. If this were so, a slight lesion of a capsular zone should be capable of producing a slight local paralysis in the face or the upper or lower limb. As a matter of fact, the clinical and anatomical researches of Pierre Marie and Guillain have shown that the most trifling lesion involving the posterior segment of the internal capsule always produces in man the syndrome of hemiplegia, and that a paralysis limited to one limb or to the face never arises from a limited lesion of the capsule, and that, in spite of the accepted anatomical diagrams, it is impossible to assign, on clinical grounds, distinct portions of the capsule to the various fibres for the arm, the leg, the foot, etc., at least in man.

(*b*) With reference to the sensory tract, it was supposed by Charcot and his followers that the various fibres of general and special sensation passed behind the motor fibres which occupy the anterior two-thirds of the posterior segment of the internal capsule (the sensory crossing), and that any lesion of that region would produce a so-called cerebral hemianæsthesia

The researches of Pierre Marie have shown that, in man, there may be destructive lesions of the so-called sensory zone of the internal capsule without persistent hemianæsthesia ensuing, and therefore there are no conduction paths, in detached groups, specialised for the transmission of sensory impressions in the internal capsule.

Site and Characters of the Wounds

The method of defining the defect in the skull in relation to the fissure of Rolando and the adjacent convolutions, either by the ordinary process of craniometry, or by the special system of radiographic datum-points suggested, has been already described.

The anatomical features of the wound do not call for remark, but if the mapping out of the rolandic cortex is practicable, the clinical picture will vary according to the site of the wound, on the one hand, with the distance up the fissure of Rolando that it extends, and, on the other, with its position in front of, or behind, that fissure; provided that the cerebral lesion is limited to the cortex, and that there is little or no destruction of the subjacent fibres of the white matter.

In view of the physiological data given above, it is to be expected that there will be brachial or crural monoplegias without sensory disturbances, or with more or less important sensory disturbances, which may even greatly predominate over the motor troubles. These monoplegias caused by injury to the cerebral cortex which are so rare in civil practice are very common results of war-wounds, which may be confined entirely to the cortex. A particularly interesting form is the double crural monoplegia from a lesion of both paracentral lobules which produces a true paraplegia of cerebral origin.

The syndrome of hemiplegia is the result of extensive lesions of the bone accompanied by destruction of the rolandic cortex and of the subjacent white matter. A wound of small dimensions, if associated with more or less profound injury of the white matter, and with or without penetration of missile, may be accompanied by a complete hemiplegia, and symptoms will often be found which indicate injury of the central grey nuclei or of the deep white nerve fibres. The wound may be quite outside the rolandic region, say in the frontal region, but the radiograph may show that a missile, which is sometimes very small, has traversed the whole of the internal capsule and been arrested in the occipital region. Several such cases have been observed.

Clinical observation is therefore a better guide in judging the importance of the cerebral lesion than the size of the wound, there being no correspondence whatever between osseous lesions and deep cerebral lesions. Monoplegias, or sensory disorders limited to a single limb, indicate a purely cortical lesion which does not penetrate to any great depth; but if there is a hemiplegic syndrome, it can be concluded that there is more or less profound destruction of the white matter underlying the convolutions, and sometimes of the fibres of the internal capsule as well. It only remains to point out that there will sometimes occur lesions of the rolandic region with the hemiplegic or monoplegic syndrome by contusion, without any loss of bone. In the examination of such cases there will be found merely a lesion of the scalp, with some irregularities of the surface of the bone of the external table; probably a hæmorrhage has occurred either superficial or deep to the dura mater leading to compression of the convolution, or even a direct lesion of the rolandic cortex (bruising of the brain, or slight intracortical hæmorrhages). The clinical picture yielded by such cases will be that of a monoplegia.

Clinical Aspects of the Wounds

MONOPLEGIAS

In civil practice true monoplegias are comparatively rare, and are seldom seen except at the beginning of the development of cerebral tumours; monoplegia through softening or cerebral hæmorrhage is hardly ever observed.

The wound.—Wounds of the skull as seen in actual war practice are frequently accompanied by a monoplegia because the lesion is merely superficial. These monoplegias can be tabulated according to the order of their frequency as, first, those of the upper limb, second, those of the lower limb, and third, those of the face. In each of these classes the site of the wound differs, and corresponds to the position in the cortex of the motor centres of the face, the upper or the lower limb given in the section dealing with the physiology of the rolandic area. In these monoplegias, which are complete, or partial, according to the seriousness of the wound, there will also be observed various disorders of sensation. These may be classified roughly in accord with the site of the wound as follows: motor disorders will be most prominent if the loss of bone is in front of the fissure of Rolando, and sensory disorders will be the most important, or may be found alone, if the lesion is situated in the ascending parietal convolution.

A. Brachial Monoplegia

The symptoms.—Immediately after receiving the wound the patient, if he has not lost consciousness, or when he regains it, realises that the upper limb is completely useless, or nearly so. In some cases the paralytic phenomena are not strictly confined to one limb; there is also more or less loss of power in the lower limb on the same side, which may disappear in

a few hours, or may persist for weeks. Monoplegia limited to the upper limb seems to be remarkably more frequent than crural monoplegia. At the first onset this monoplegia is flaccid, and passes into

FIG. 9.—Usual seat of the wound in brachial monoplegias from a cortical lesion.

contracture after a few weeks, which is generally the time when the patient is examined by the neurologist. It is important to observe that this monoplegia is slight, and much less marked than the complete hemiplegia to be described later on.

Motor disorders.—Total loss of the motility of the limb is rarely observed. The power of moving the shoulder is nearly always retained, and, to a certain extent, the patient is able to raise his arm and move it slightly from the thorax. In repose the patient's forearm is slightly bent on his arm, and in pronation with the wrist slightly bent and the fingers flexed or incompletely extended. In this very accentuated

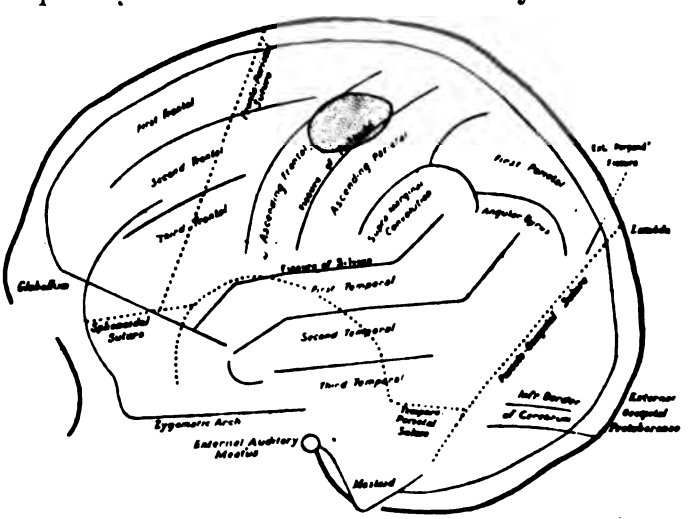


FIG. 10.—Radiographic localisation of wounds in the rolandic area causing a brachial monoplegia. (Method of Pierre Marie, Foix, and Bertrand.) The dotted zone indicates the projection of the loss of bone on the subjacent convolutions.

form of monoplegia a test of the segmental power will show a preponderating affection of all the extensors of the fingers, wrist, and forearm, of the external rotators and of the abductors. The flexors, internal rotators, and the adductors will be relatively much more active. In most cases there is also slight impairment of the motor power of the lower limb.[1] The

[1] The test of the combined flexion of the thigh and trunk suggested by Babinski (see Differential diagnosis) will give an elevation of the lower limb on the monoplegic side which is not reproduced on the healthy side.

face presents a slight degree of asymmetry, and the contraction of the superficial muscles is more feeble on the side affected by the monoplegia. We find, in short, limited to the upper limb, the motor disorders observed in a case of complete hemiplegia from a deep wound of the brain.

In another class of cases the paralysis affects equally all the muscles of the upper limb, and the arm hangs useless at the side. As a rule the paralysis is more localised; it assumes a segmental topography, and is apparent only in all the movements of the hand, or more rarely of the shoulder.

In cases of greatly diminished paralysis, or in which the monoplegia has been originally very slight, a still more marked limitation of the motor troubles having a segmental topography may frequently be observed; only certain groups of muscles in the hand, or much more rarely at the root of the limb, continue to be affected. In these cases of partial monoplegia general weakness of all the movements of the fingers may be observed (extension or flexion being performed without energy), or there may be paresis limited to the movements executed by the interossei, or by some of them, to such an extent that the position of the hand resembles that observed in slight paralysis of the ulnar nerve. One case has been observed in which the motor troubles were limited to the movements of the middle finger only. It is therefore always absolutely necessary to test methodically the movements executed by the various portions of the upper limb.

Examination of the tendon reflexes will show changes; there is nearly always increase in all the reflexes on the same side as the monoplegia, which is more marked in the paralysed limb.

With the exception of the plantar, the cutaneous reflexes are often normal. Free flexion of the toes is

seldom found, and the test pretty frequently evokes no response. Attention should be called to the comparative rarity of the typical Babinski sign; stimulation of the sole of the foot does not cause extension of the toe, often a mere suggestion of separation of the toes. On the other hand, the test for adduction, by scratching the inner border of the foot, often gives a positive result, while a similar procedure on the outer border causes flexion of the toes.

Disorders of sensation.—Disorders of sensation, either superficial or deep, are almost the rule in the brachial monoplegias which are not purely of the motor type. Sensory disorders in the form of complete or partial hypoæsthesia on the half of the body corresponding to the monoplegia are frequently observed in connection with wounds corresponding to the superior portion of the rolandic region. At the level of the upper limb the disorders of the sensibility are very strongly marked, and assume a segmental distribution. They are seldom complete; more often they conform to the accepted cortical sensory syndrome with nearly complete integrity of the osseous and thermic sensibility and of the sensations of touch and pain, but very marked diminution of the tactile sensibility and of the sense of attitude, accompanied by astereognosis. But this syndrome is far from being the rule; very various isolated disorders of sensibility may be observed, especially a diminution, almost exclusively, of the sensations of pain, temperature, and vibration. No explanation of these variations has as yet been arrived at.

These sensory disorders often assume a special topography of a radicular type which had been previously observed, but is frequently met with as a result of wounds of the skull. These sensory failures are arranged in longitudinal bands over each segment (the hand, forearm, and upper arm) which sometimes

do not correspond in breadth, and are generally more marked at the extremity than at the root of the limb. It is important to know that anæsthesia of cortical origin may thus assume a pseudo-radicular type.

These sensory troubles are sometimes very persistent, and in a certain number of cases, when the motor troubles have entirely disappeared, there is only an improvement of the stereognostic sensibility

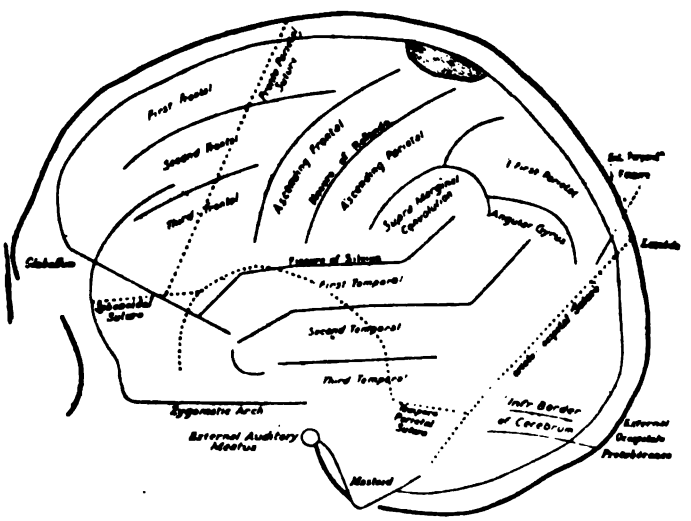


FIG. 11.—Radiographic localisation of wounds in the rolandic area causing a crural monoplegia or a cortical paraplegia. (Method of Pierre Marie and Foix.) The dotted zone indicates the projection of the loss of bone on the subjacent convolutions.

to be observed. This astereognosis may extend to the whole hand, or may be limited to the radial (thumb and index finger) or the ulnar portion (the three last fingers). This limited loss of the stereognostic sense is the last vestige of an old cortical lesion, originally very slight or in an advanced stage of cure.

The vasomotor and trophic disorders vary greatly in importance. There may be œdema and cyanosis

of the integuments in strongly marked monoplegias, or merely an alteration in the colour of the affected hand in cases of slight cortical lesions.

B. Crural Monoplegia

Pure, isolated crural monoplegias are more rarely seen than brachial monoplegias.

The same peculiarities may be observed as in brachial monoplegias. Sometimes there is a monoplegia affecting the entire limb. Methodical examination of the segmental muscular power will show predominant injury of all the muscles employed in shortening the limb, viz. the extensors of the foot, the flexors of the knee and thigh, and the adductors; in short, the opposite type to that of brachial monoplegia. More often the monoplegia is segmental or partial, variable in type, and frequently limited to the movements of the foot. It conforms to the type of a peripheral paralysis in the area of distribution of the external popliteal nerve with loss of voluntary extension of the toes, which, however, is retained in the automatic motions of walking. This peculiarity will be dealt with later.

The patellar and tendo Achillis reflexes are brisk; there is frequently ankle clonus, and sometimes reflex shortening of the limb.

The cutaneous reflexes are modified. The plantar cutaneous reflex often produces extension of the toes, but in the type of monoplegia limited to the extensors of the foot and toes described above, there is frequently no response at all to the plantar cutaneous excitation. The sign of adduction is very often observed. It is often impossible to obtain the cremasteric reflex on the side of the monoplegia.

The disorders of sensibility assume the segmental or pseudo-radicular type, and the modifications of deep sensibility are often strongly marked.

Trophic disorders.—Œdema, cyanosis, and coldness are more marked than in brachial monoplegia. Double crural monoplegia, amounting to a true "cortical paraplegia" from a lesion of the paracentral lobules. is very frequent.

Cortical Cerebral Paraplegia

The wound.—This clinical form is always dependent upon wounds of the vertex, generally tangential, which reach the two paracentral lobules where the centres for the movements of the lower limb are situated (see Anatomy and Physiology above). As the lesions of the two lobules are seldom symmetrical, a more or less marked predominance of symptoms is generally found in one of the two lower limbs.

Symptoms.—Immediately after the wound there is a complete flaccid paralysis, and the patient often speaks of transitory paralytic phenomena in the upper limbs. Trouble with the sphincters often occurs at first, after which the flaccid paralysis soon becomes spasmodic. Examination of the patient then shows paralysis of the lower limbs; diminution of the segmental muscular power of the retractors of the limb, more marked at the extremity than at the root of the limb; exaggeration of the tendon reflexes in both upper and lower limbs, with ankle and patella clonus and reflex retraction of the limb; the reflex of extensor action of the toes, or reflex adduction of the foot; loss of the cremasteric and abdominal cutaneous reflexes; irregular disorders of sensation, very frequently of deep sensation; alteration in the gait, such as spasmodic action and walking as if ascending a staircase. These are briefly the signs of double crural monoplegia.

This spasmodic paraplegia, which is so special to war-wounds, displays a very striking variety of clinical forms.

1. *Spasmodic paraplegia with retention of the spinal automatism of the movements in walking.*—In certain cases examination of the segmental muscular power reveals complete inability to execute certain movements voluntarily; this generally takes the form of inability to raise the toes and the foot voluntarily. If the paralytic phenomena are only slight, and the patient can still walk, though with difficulty, it will be found that raising the toes and the foot, though impossible voluntarily and alone, is executed correctly, though unconsciously and involuntarily, while walking. If the patient is too extensively paralysed to walk, this automatic movement can sometimes be produced by telling the patient to bend his leg sharply on his thigh; then on trying to oppose the movement the foot may be seen to become dorsiflexed and the toes to be extended. This phenomenon is very probably a result of spinal automatism, while the loss of the voluntary motor power is caused by lesion of the cerebral cortex.

2. *Cortical spasmodic paraplegia with disorders of co-ordination of movement.*—This is a particularly interesting form of cortical paraplegia. The clinical picture is that of spasmodic paraplegia with the addition of more or less marked want of co-ordination. If the patient is told to put his heel on the opposite knee, or up to his thigh, or to touch the observer's finger with his toe, the movements will be carried out comparatively correctly while the eyes are open, but when he shuts his eyes the movements will be executed with wide oscillations and overshooting the mark, as is observed in cases of tabes. The walk will also be profoundly altered, and often very considerable ataxia, as well as spasmodic action, will be apparent. In these cases it is absolutely necessary to make a very careful examination of the deep sensation, which will always show very marked alteration of the sense of

position and of passive movements, and the tuning-fork test will show that the sensibility to vibration is also affected. In short, it is a case of spasmodic paraplegia with ataxia, very probably of cortical origin, through loss of deep sensation.

Marked disorders of co-ordination of an asynergic, and not an ataxic, type are not so frequent. In these cases the disorders of co-ordination are as evident when the eyes are open as when they are shut. The movements are immoderate rather than inco-ordinated, and there is no indication of alteration of deep sensation. These patients totter when they walk, they widen their base of support, and present every sign of injury to the cerebellum. The explanation of this cerebellar form of cortical paraplegia is obscure. It might be assumed that the cerebellum has been injured by the traumatism, by "contre-coup," but there is no definite anatomical evidence of this hypothesis; nevertheless it is important to get an explanation of this special form of paraplegia in cases of wounds of the vertex.

Facial Paralysis of Cortical Origin

The wound.—In some cases of very small wounds low down in the rolandic area there will be asymmetry of the face due to facial paresis on the side opposite to the wound.

Symptoms.—In the most characteristic cases this facial paresis is not accompanied by hemiplegia, and there is only a very slight alteration in the tendon reflexes of the limbs; the reflexes will be stronger on the side of the facial paresis. This paresis is most marked in such acts as speaking or whistling. Shutting the eye is easily done, but the patient finds it either difficult or impossible to shut the eye on the paralysed side alone, though he has no difficulty in shutting

the eye on the sound side. It has appeared to us that the paralysis always affects mainly the lower part of the facial nerve. There is no alteration in the electric reactions of the nerve or of the paralysed muscles.

This type of facial paralysis of cortical origin due to lesion of the facial centre is seldom met with, but it is important to know of it for the purpose of differential diagnosis. It must not be confused with the patchy and peripheral type of paralysis seen in cases of anterior and lateral wounds of the frontal region, which only affect the upper part of the facial nerve; in these cases there is paresis or marked paralysis of the frontal muscle, with inability to raise the eyebrows.

There is also another type of facial paralysis of the peripheral type which is found in wounds of the skull accompanied by fracture spreading to the base. This is a complete facial paralysis of the peripheral type (Bell's paralysis) sometimes associated with paralysis of the sixth or eighth cranial nerves. As with the last form described, this form of peripheral paralysis is situated on the same side as the wound, and is accompanied by alterations in the electric reactions of the facial and of the muscles innervated by it. It is due to lesion of the facial nerve in the petrous bone.

HEMIPLEGIA

The wound.—As has been stated above, complete hemiplegia is the result of an extensive wound of the rolandic area, or of a lesion penetrating to a great depth, although it may appear to be trifling. Wounds, the topography of which does not correspond to the rolandic area, may be accompanied by grave hemiplegia. In these cases the radiograph nearly always shows the presence of a missile in the brain, often very small, and frequently far away from the point

of entry into the skull. The missile in its passage has destroyed the fibres of the corona radiata or of the internal capsule (fig. 12). When there is such a total persistent hemiplegia of the accepted type it may be assumed that the cerebral lesion is not merely superficial and cortical, but that the white matter is

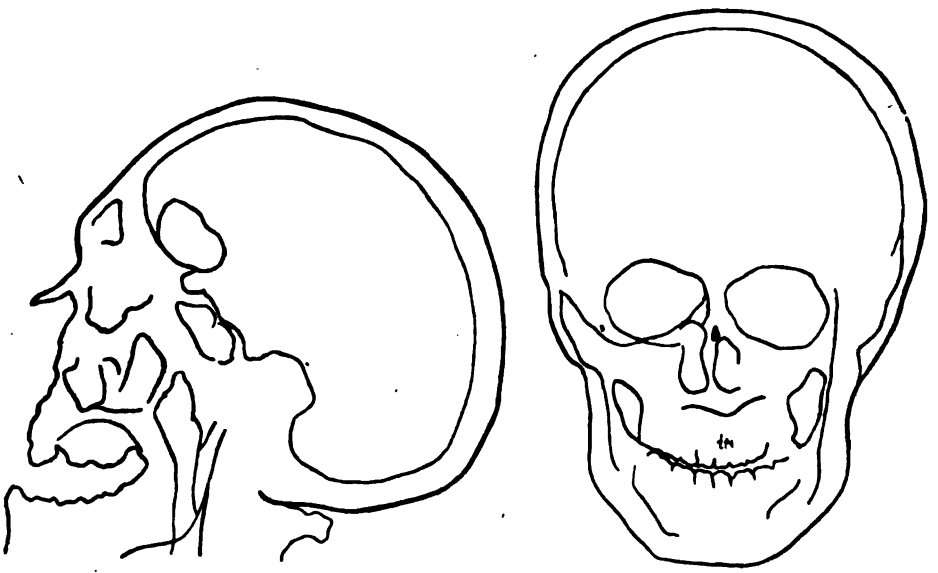


FIG. 12.—Radiograph of the skull (full face and profile) in a case of complete hemiplegia following a wound of the frontal region. The radiograph shows the existence of an intracerebral missile (the small black dot) which has traversed the internal capsule and has been arrested in the occipital lobe near the median line. The orifice of entry is near the lateral frontal region.

also more or less deeply involved, although the cortical lesion may be small in extent. This idea of complete syndromes through even a limited lesion of the white matter is most important; established by Pierre Marie and Guillain for cases of small vascular lesions of the internal capsule, it receives further confirmation in cases of traumatic lesions of the brain.

Symptoms.—As the clinical picture of hemiplegia

due to a wound does not present any special features, the symptoms need not be described in detail; they are to a great extent the same as those of the common hemiplegia from softening or hæmorrhage. Immediately after the wound half the body is completely paralysed, the limbs are limp, and the reflexes are diminished or suppressed, but after a few weeks contracture appears, and the picture becomes the accepted picture of hemiplegia with contracture.

The patient presents the following appearance :—

In the upper limb there is flexion contracture, the fingers are strongly flexed on to the palm, with the thumb turned in or not, the wrist flexed on the forearm, the forearm on the upper arm, the arm applied more or less closely to the body and rotated inwards, while the shoulder droops.

In the lower limb there is contracture in extension of the whole limb; the foot is adducted and inverted.

In the face, contracture is not generally observed; the facial paralysis is more or less strongly marked, but the upper part of the facial is much less involved than the lower If the patient is told to open his mouth very wide, the platysma on the paralysed side contracts very slightly or not at all (Babinski).

The tongue, when protruded, deviates to the paralysed side.

The above account of the position of the limbs and the facial appearances applies to the general run of cases, but it is not unusual for the contracture to occur in extension, instead of flexion, in some parts of the upper limb, or, much more rarely, in flexion in the lower limb.

The gait is characteristic; the lower limb, being contracted in extension, is brought forward at each step by a movement of circumduction; the patient scrapes his foot, and frequently drags the ends of

the toes along the ground. While walking, the arm remains almost immobile and slightly abducted.

All the *tendon reflexes*—the Achillis, patellar, radial, and tricipital—are exaggerated on the paralysed side; the contralateral reflex of the adductors is often seen.[1] There is frequently also clonus of the ankle and patella, and sometimes of the hand.

The cutaneous reflexes are modified. In most cases the plantar cutaneous reflex is extensor, but if there is a slight hemiplegia it may be absent and instead there is the adduction reflex, which has been described above. The cremasteric and abdominal cutaneous reflexes are frequently lost or very weak on the paralysed side.

Disorders of sensibility are common, but vary considerably in type and distribution.

Disorders of tactile sensation are usually more marked in the limbs than in the trunk, in which latter the anæsthesia does not extend to the median line but stops at a little distance short of it.

The sensibility to pain is often modified in a peculiar manner; there is not complete anæsthesia; it can hardly even be said that there is hypoæsthesia, but rather a true hemiagnosis; the patient is sensible of pain, but cannot describe the cause of the painful sensation nor locate it (Pierre Marie). In most cases the disorders of sensation improve more rapidly than do those of motion.

The deep sensation is very often impaired, sometimes to an extent corresponding with the superficial sensation, and sometimes to a greater degree.

The stereognostic test should always be applied in a case of hemiplegia if the paralysis is not too

[1] This pathological reflex, which has been described by Pierre Marie, is obtained by percussion of the tendon of the patella on the healthy side; a contraction of the adductor muscles of the thigh on the paralysed side is thus produced, which is visible under the integument, and is made evident by a movement of adduction in the thigh.

profound to allow it; astereognosis is frequently found, and this disorder lingers long afterwards as a sequela in a nearly cured hemiplegia.

The *trophic and vasomotor disorders* vary in intensity. When the hemiplegia and contracture are strongly marked, there will be œdema of the extremity of the limb, with lividity of the skin, and very often a reduction of the local temperature.

Amyotrophia is a peculiar and comparatively rare trophic disorder. This may be very marked, and is undoubtedly connected with anatomical lesions of a particular locality; it is generally complete, but it appears to be most pronounced about the root of the limb. The electrical reactions of the muscles and nerves are usually normal.

The foregoing is a description of the usual clinical picture of hemiplegia from a wound of the cortex and the white matter of the rolandic convolutions, but it may be modified; certain symptoms may become predominant, and new symptoms may arise, according as the seat of the lesion is evidently in front of, or behind, the fissure of Rolando, and especially in proportion to the depth of the cerebral lesion.

Clinical varieties of hemiplegia.—By taking the site of the lesion as a basis, it is possible to draw out an approximate plan for distinguishing wounds of the prerolandic area from those of the post-rolandic area.

Lesions evidently situated on the ascending frontal are accompanied by a maximum of motor disorders, while the sensory disorders are not usually persistent. These are the cases which conform to the accepted type of complete hemiplegia. In wounds in the post-rolandic area the hemiplegia is less strongly marked, and frequently becomes so nearly cured as to cease to be apparent except by differences in the tendon reflexes and modifications of the cutaneous reflexes; on the other hand, the sensory disorders, especially

astereognosis, are extremely persistent. Patients who have wounds in this locality should always be tested for astereognosis.

Deeply penetrating wounds with extensive destruction of the white matter, or penetration of the missile deep into the brain, are characterised by symptoms in addition to the accepted syndrome of hemiplegia. In certain cases it is possible by these symptoms to estimate exactly the extent of the destruction of cerebral matter and to diagnose the presence of a missile in the brain. Thus, injury of the central grey nuclei is shown by peculiar sensory phenomena; by more or less severe pains all over the paralysed side; very evident disorders of the deep sensation, hemiataxia or hemiasynergia, involuntary movements resembling those of athetosis, and frequently visual disorders consisting of a homonymous lateral hemiopia on the same side as the hemiplegia, or by quadrantic hemiopia.

Penetrating wounds of the rolandic area reaching the peduncle or the pons appear to be quite exceptional, even if they ever occur. The existence of paralysis of the third, sixth, seventh, and eighth cranial nerves is not sufficient evidence on which to base a diagnosis of alternate hemiplegia. These paralyses are much more likely to be caused by fracture of the vault of the skull, extending to the base, associated with lesion of the trunks of the nerves, than by direct lesion of the peduncle or of the pons.

Marked total amyotrophy along the whole side affected by the hemiplegia is good ground for thinking that there is a deeply penetrating wound, perhaps reaching to below the thalamus or to the peduncle (Georges Guillain and Barré); but very strongly pronounced amyotrophy has been observed with extensive superficial wounds which are unmistakably parietal.

Disorders of speech are purposely omitted here, as they will be made the subject of a special chapter (Chapter VII.).

Diagnosis.

In all cases of wounds of the rolandic area a complete examination of the motor and sensory functions of the patient is necessary in order to obtain an accurate idea of the extent of the cerebral lesion, and to form a definite opinion that it is a case of organic and not of functional hemiplegia.

DIFFERENTIAL DIAGNOSIS BETWEEN ORGANIC AND FUNCTIONAL HEMIPLEGIA.—By means of a series of most important clinical researches Babiński has formulated a series of tests which should be methodically applied whenever there is any doubt as to whether the disorders are organic or functional. The first question which arises in dealing with paralysis of hemiplegic or monoplegic character is as to whether it is a case of organic hemiplegia arising from a cranial wound or lesion of the subjacent cerebral region, or whether it is not rather a case of purely functional disorder or, to follow the accepted nomenclature, hysterical.

Clinical characteristics of functional (hysterical) hemiplegia.—Hysterical hemiplegia is generally a partial paralysis which remains partial, or the paralysis is spasmodic from the first.

The osseous, tendinous, and cutaneous reflexes are normal and equal on both sides. The gait is characteristic, the patient drags his paralysed leg behind him, he does not scrape the ground with it. There is very frequently hemianæsthesia of the whole of the paralysed portion of the body associated with the hemiplegia; the hemianæsthesia is of every type, and is generally complete. Or there may be anæsthesia affecting a leg-of-mutton or collar-shaped area, as described by Charcot. Double amblyopia is equally common,

or it may be unilateral. In most cases this clinical picture, when it occurs in an evident case of hemiplegia, enables the diagnosis to be made; but when the symptoms of paralysis are not very pronounced, it will be necessary to make the most thorough examination of the patient. The very varied clinical indications pointed out by Babinski which under these conditions enable organic hemiplegia to be distinguished, as certainly as is possible, from hysterical hemiplegia should be methodically looked for as follows :—

In the face.—The indication of the platysma myoides. If it is a case of organic hemiplegia the platysma contracts well on the healthy side, but feebly or not at all on the paralysed side, in certain acts such as opening the mouth wide, showing the teeth, etc.

In the upper limbs.—In partial organic flaccid hemiplegia the degree of passive flexion of the forearm on the upper arm, when carried as far as possible, is greater in the paralysed than on the healthy side. This is called the phenomenon of exaggerated flexion of the forearm.

If both hands of a patient suffering from organic hemiplegia are put passively into the supinated position and are left alone, the paralysed hand involuntarily becomes pronated.

The phenomenon of the interossei (Souques). If the patient the subject of organic hemiplegia is told to raise the paralysed arm, his fingers will spread out fanwise when carrying out the movement.

While walking, the balancing movements of the arms, which are normally performed inversely to the movements of the thighs, are not seen in a case of functional hemiplegia, or the movements may even be made in harmony.

In the lower limbs.—In addition to the plantar cutaneous reflex with extension of the toes, the

contralateral reflex of Pierre Marie, and the clonus of the ankle and the patella, already described, which are only seen when there are lesions of the pyramidal tract, there are other clinical symptoms of great value which are only found in organic hemiplegia.

Combined flexion of the thigh and trunk.—The patient being extended on a rigid couch is told to cross his arms and try to sit up. If it is a case of organic hemiplegia, the lower limb on the paralysed side will be seen to raise itself, the thigh will bend and the heel will rise from the couch, while on the sound side the heel will remain flat on the couch and the whole limb will be immobile. When the patient succeeds in sitting up, the same movement will be repeated if he falls quickly backwards. This combined flexion of the thigh and trunk is not met with in cases of functional hemiplegia.

Strümpell's phenomenon is an associated movement of adduction and inward rotation of the foot, produced when the patient's paralysed leg is lying on a firm couch and he is told to flex the leg on the thigh while the movement is opposed by the observer.

The phenomena of associated adduction and abduction have also been described (Raimiste). The patient lies extended flat with his legs spread out, and is told to bring the sound leg to the paralysed one; if the observer opposes the movement, the paralysed leg will make a movement of adduction. An analogous phenomenon of abduction associated with the paralysed side will be seen if the observer opposes the movement of abduction of the sound leg.

According to Grasset, a patient who is the subject of organic hemiplegia can raise the paralysed leg by itself, but he cannot raise both legs simultaneously.

Other less important indications have been described, but it is not worth while to specify them, as those given above are amply sufficient to allow of an exact

diagnosis, and to distinguish with certainty between organic and purely functional hemiplegia. These distinctive indications have been set forth in such detail because the problem is constantly arising, and the first necessity for an exact and correct diagnosis is all the evidence procurable.

Course of lesions of the rolandic area.—The course of the hemiplegias or the monoplegias, consequent on wounds of the rolandic area, is infinitely variable, but a distinction must be drawn between purely cortical wounds giving rise to sensory and motor monoplegias, and the hemiplegias which are almost invariably due to deep-seated lesions.

Pure monoplegias, whether total or dissociated, show an evident tendency to improve. Motor disorders generally decrease more rapidly under proper treatment than sensory disorders, whose sequelæ often linger for months as evidence of the lesion of the cortex; astereognosis, for instance, may remain as the sole symptom of a lesion of the rolandic area for several months or years after the wound.

On the other hand, hemiplegias in which the lesion of the white matter and of the central grey nuclei is much more important than the lesion of the cortex generally become spasmodic after a few weeks, and improve only very slowly. For months or years afterwards there is great awkwardness in the more delicate movements, such as those of the hand particularly. The contractures diminish only by degrees, and if the treatment is neglected, articular rigidity supervenes, and even ankyloses may occur, further increasing the awkwardness of the movements due to the spasmodic character of the hemiplegia. The *complications* of wounds of the rolandic region have nothing special in their character, and will be dealt with later in the chapter on "Complications of Wounds of the Brain."

Treatment.—Treatment by physiotherapy should be applied as early as possible, and should consist mainly of massage of the limbs on the paralysed side, with movements of the joints, and mechano-therapy. The patient must not be allowed to remain in his bed, but must be made to get up and walk as soon as ever the condition of the wound will allow of it. Caution should be observed in applying electric treatment (static), which is only of secondary utility.

CHAPTER V

WOUNDS OF THE PARIETAL LOBE

Anatomy

THE parietal lobe is situated in the superior median portion of the hemisphere, above the Sylvian fissure which divides it from the temporal lobe, behind the fissure of Rolando which divides it from the frontal lobe, and in front of the external occipital fissure which bounds the occipital lobe. The boundaries of the lobe, which are very clear in front (the fissure of Rolando) and at the base (the Sylvian fissure), are not so clear at the back, where the parietal convolutions are united with the temporal and occipital lobes. Above and mesially the parietal lobe forms a good third of the superior convex border of the hemisphere. It is of interest to note that the parietal lobe corresponds to the parietal bone, but that the bone extends beyond the limits of the lobe in every direction; the centre of the parietal eminence corresponds to the point of junction of the two convolutions which make up the inferior parietal convolution.

The parietal lobe includes three convolutions, a vertical anterior (the ascending parietal) and two horizontal (the first or superior, and the second or inferior). These two convolutions are separated by a single sulcus in the shape of a horizontal T, which is called the intra-parietal sulcus. The ascending

parietal has already been dealt with in connection with the rolandic area, of which it has been considered a part.

The superior or first parietal convolution springs from the ascending parietal by a broad-based foot; it follows the superior border of the hemisphere, impinging on both its aspects, and describing S-shaped curves, principally in a vertical direction. Posteriorly it narrows into a connecting fold, which turns round the end of the external occipital fissure (the first external parieto-occipital arcus or fold of transition of Gratiolet), and is directly continuous with the first occipital convolution. This convolution has two aspects, an external (the superior parietal) and an internal on the inner aspect of the hemisphere, which is termed the quadrate lobule or precuneus, and is bounded in front by the subfrontal fissure, behind by the occipital fissure, and slightly separated below by a shallow sulcus from the corpus callosum.

The second or inferior parietal convolution springs from the foot of the ascending parietal by a single root, which forms part of the rolandic operculum and covers the island of Reil; it then runs up alongside the ascending parietal, turns round the end of the Sylvian fissure and the end of the first temporal sulcus, and then bifurcates, one part being continued into the second temporal convolution, and the other passing by a connecting fold into the second occipital convolution. This convolution has a very complicated appearance; it has two important curves, a bulky one which surrounds the posterior extremity of the Sylvian fissure forming the marginal lobule or gyrus supramarginalis, while the other turns round the posterior extremity of the first temporal sulcus forming the gyrus angularis.

The very deep intra-parietal sulcus which separates the parietal convolutions has the appearance of a T

laid on its side, with its vertical limb parallel to and behind the fissure of Rolando, while the horizontal branch is parallel to the superior border of the hemisphere, and separates the superior from the inferior parietal convolution. This sulcus is continuous with

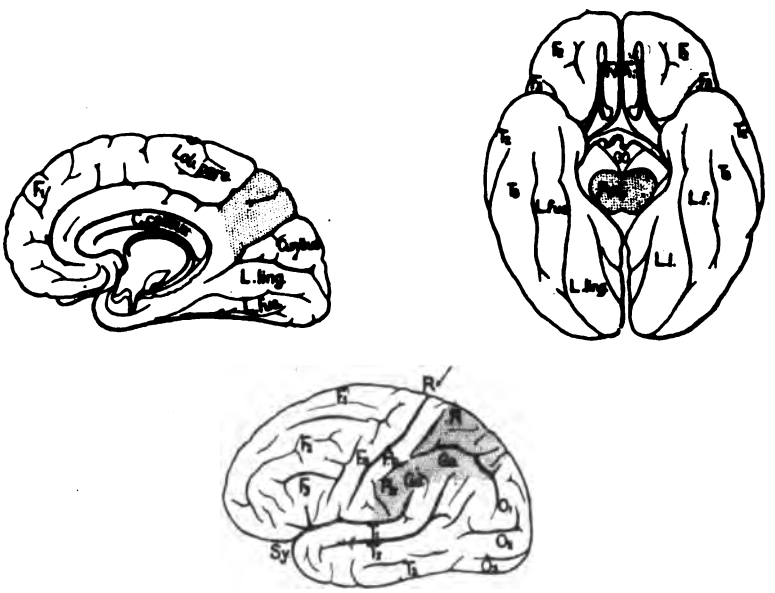


FIG. 13.—External and internal aspects of one hemisphere and inferior aspect of the brain.

The convolutions are marked by a letter with an indicator; F_1, first frontal; Fa, ascending frontal, etc.; Ga, gyrus supramarginalis; Ga, gyrus angularis; R, fissure of Rolando; Sy, Sylvian fissure; Lob. para, paracentral lobule; L. ling, lingual lobule; L. fus, fusiform lobule, etc.

the first occipital sulcus on the external aspect of the occipital lobe.

It is interesting to refer to the cellular architecture of these convolutions. According to Brodmann's researches, the parietal region has a homotypical structure in six strata, which are distributed in the first and second parietal convolutions (to the exclusion

of the ascending parietal) and the precuneus. This difference of cellular architecture is a further justification for dealing separately with the ascending parietal convolution.

Physiology

All our knowledge of the physiology of the parietal convolutions is derived from anatomical and clinical researches on the sick and wounded the data founded thereon being very rudimentary, as will be seen later. Founding his theoretical reasoning on comparative anatomy and on researches in myelo-genetics, Flechsig thought that he had located the site of the centres of association of the sensitive and sensory perceptions, which he named "the great posterior association centre," but human pathology has not furnished any confirmation of this purely theoretical conception. The physiology of the parietal lobe will therefore be considered here by the light afforded by the symptomatology of the wounds of this lobe.

Symptoms

The wound.—Wounds of the parietal lobe are fairly common, especially those of moderate dimensions not exceeding the diameter of a five-shilling piece. They have no special features, and may be superficial, involving only the cortex, or extending, with or without the presence of a foreign body, into the brain.

I. Absence of symptoms.—In a certain number of parietal wounds, in which the cortex has probably been injured (as shown by pulsation and impulse on coughing), or certainly injured (according to the history sheet), there are no symptoms apparent. It is impossible to state definitely the reasons why a lesion of the parietal lobe does not show any symptoms. It would seem from the cases we have observed that

the dumb area is in the first parietal, especially its posterior portion, the precuneus. At least this is what has been observed in soldiers several weeks or months after the wound has been inflicted.

II. Disorders of sensibility.—These are the most common disorders found as the result of parietal wounds, and affect almost exclusively the deep-seated sensibility, viz. the idea of position and the perception of passive movements. While the perception of superficial sensibility appears to be located principally in the ascending parietal, the deep-seated (or muscular) sensibility is probably located in the first and second parietal, but it is not possible to lay down its segmental distribution more precisely. The localisation would seem to be analogous to the distribution of the motor functions in the ascending frontal.

Examination of the patient will show more or less marked disorder of the idea of position extending over the whole limb or confined to its distal extremity. If the patient's fingers or toes are slowly moved, he cannot describe the movement or reproduce with his sound hand a position given to his paralysed hand. It is not unusual to find ataxic disorders (cortical ataxia) limited generally to the lower limb, or in rare cases to the upper limb, associated with these disorders of the sensibility. This ataxia, arising from loss of deep-seated sensibility, and limited to the lower limb, may be observed quite apart from any symptoms of lesion of the pyramidal tract. It is generally bilateral, and when associated with a spasmodic paraplegia is the ataxic form of cortical paraplegia previously described. It must be remembered that in these cases we are dealing with wounds of the vertex which the radiograph has shown to be located behind the fissure of Rolando, that is, in the region of the paracentral lobule and the first parietal on both sides.

Examination for deficiency in the stereognostic

sense is very important in these cases. Stereognosis is not merely a form of sensation, but is due to the simultaneous employment of superficial and deep-seated sensation, and it is not necessary that there should be simultaneous lesion of both these to cause its loss, and it is therefore impossible definitely to locate it. It must also be borne in mind that astereognosis may occur in other complaints than lesions affecting the cortex. It is nevertheless the fact that astereognosis in the whole hand, or part of it, may be met with as the sole symptom of a parietal lesion or as its sequela. Even when there is no other indication of nervous lesion astereognosis must always be sought for, since a careful examination of the various forms of sensibility will often show disorders, sometimes very limited but indisputable, of the muscular sense, slighter injury of superficial sensation, and especially of tactile discrimination, and of the sense of localisation in the hand, associated with the astereognosis.

III. Aphasic disorders.—These arise only when the second or inferior parietal on the left side is involved, more especially its posterior part, which constitutes the gyrus supramarginalis and the gyrus angularis. These aphasic disorders, which resemble Wernicke's aphasia in type, will be dealt with in the chapter on "Aphasia and Wounds of the Brain" (Chapter VII.).

IV. Apraxic disorders.—It is common knowledge that apraxia, the syndrome of which has been worked out by Liepmann, consists in inability to execute the movements required to carry out a definite action, although there is no paralysis. Several varieties are distinguished, of which the idealogical and the ideomotor are the most important.

Idealogical apraxia is essentially a disorder of the intelligence similar to, if not identical with, that observed in Wernicke's aphasia, and belongs to the

group of intellectual modifications characteristic of aphasia.

Ideomotor apraxia is very peculiar in its manifestation, and is a special motor disorder. While the patient affected with ideological apraxia is unable to picture mentally the succession of movements required to perform a definite, more or less complicated, action, the patient affected with ideomotor apraxia, although he knows quite well the successive movements required, cannot carry them out, or carries them out all wrong, or with the greatest awkwardness. Ideomotor apraxia appears to occur both in association with aphasic disorders and apart from them; it is therefore evident that it is extremely difficult to discriminate how far the disorder is due to aphasia and how far to apraxia.

Apraxia is very probably caused by lesions of the left parietal lobe, the inferior parietal, and more especially the gyrus supramarginalis. Although the lesion may be situated on the left side of the brain, the apraxic phenomena are usually bilateral, and in certain cases are more marked in the homolateral limb.

Tests for apraxia.—Practical evidence of ideomotor apraxia is obtained by causing the patient to perform a series of actions with one hand at a time, or with both hands.

(*a*) He is told to perform a simple action, such as raising the hand, shutting the eyes, crossing the legs, putting out the tongue, giving a fillip, putting the fingers to the nose and spreading them out ("cocking a snook"), saluting, clapping his hands, wagging his finger at someone, blowing a kiss.

(*b*) He is told to perform an act connected with an external object by lighting a cigarette, putting on a stamp and sealing up a letter, locking a door, pouring water into a glass, etc.

(*c*) He is told to describe the actions from memory without performing them, to describe how a postage-stamp is fixed on, how a match is lighted, etc.

(*d*) He is required to repeat some action just performed in his presence.

(*e*) He is kept under observation while eating and dressing. It must be understood that these disorders are significant when there is neither paralysis nor aphasia; this rarely occurs, but whenever there is a lesion of the left parietal lobe unassociated with paralysis or aphasia, or sensory disorders, it is necessary to make these tests.

Stress must be laid on the importance of the search for those modifications of the deep-seated sensibility so frequently associated with lesions of the parietal lobe, as they may be the cause of ataxic phenomena, and of awkwardness in the movements, which must not be taken as indications of apraxia.

The above are the symptoms observed in cases of wounds of the parietal lobe, especially on the left side, whether the lesions are purely cortical or affect slightly the subjacent white matter. It must be borne in mind that these disorders do not always occur, and there are cases in which the most thorough clinical examination fails to find any indication of cerebral lesion, especially when the superior parietal convolution only is involved.

Associated symptoms.—Symptoms indicating lesion of the deep white fibres (the corona radiata, internal capsule, and optic radiations) and of the central grey nuclei may be observed when the wound penetrates deeply or there is extensive destruction of the parietal lobe. The most important are hemiplegia and hemiopia.

The *hemiplegia* is of the central type, that is, complete hemiplegia with contracture, and is often associated with cerebral hemianæsthesia, which is

shown by predominant loss of the deep-seated sensibility and sense of location, but is very seldom persistent.

The *hemiopia* is of the homonymous lateral type, is total in the early months, and is slowly modified until there only remains a hemiopic diminution of the field of vision, sometimes complemented by hemiachromatopia. It must be understood that the hemiopia may be complete and permanent if the missile has penetrated to a great depth and severed the optic radiations. When the homonymous lateral hemiopia is on the right side, and the left parietal lobe has therefore been injured, it is not unusual to find alexia associated with it. This is a peculiar disorder, which belongs to the aphasic group, and will be dealt with in that connection.

It must be added that in cases of a deep lesion of the parietal convolutions, associated with hemiplegia or hemiparesis, there is always a possibility of hemiatrophy, often very strongly marked, supervening. In these cases it is difficult to say whether this hemiatrophy really arises from the lesion of the parietal convolutions or from concomitant lesion of some portion of the central grey nuclei.

Course

The course and prognosis of wounds of the parietal lobe vary widely according as the lesion affects the right or the left lobe on account of the aphasia associated with the latter. If the wound is superficial there will be little more than disorders of sensibility, which almost always go on to a slow recovery, although the modifications of the stereognostic sense may be very persistent. If the lesion is a deep one, the course of the case is the same as in the spasmodic hemiplegia, already described in connection with wounds of the

rolandic area. Unless the missile has penetrated very deeply, the hemiopia nearly always improves. On the other hand, if there is aphasia, nearly resembling the sensory aphasia of Wernicke, the prognosis of wounds of the left parietal is greatly aggravated. As a rule the patients remain permanent invalids incapable of following any calling.

CHAPTER VI

WOUNDS OF THE TEMPORAL LOBE

Anatomy

THE temporal lobe is situated below the parietal lobe, from which it is divided by the Sylvian fissure, and in front of the occipital lobe. It has an external and an internal aspect, an internal border and an anterior pole. Its posterior border is continued without a break into the occipital lobe. Its external aspect includes the three first convolutions; the two others are on the inferior aspect.

It is very important to describe briefly the position of the temporal lobe relatively to the bones of the cranium. The temporal lobe occupies the temporo-sphenoidal fossa, the middle fossa of the base of the skull, formed by the greater wing of the sphenoid, the internal aspect of the squamous portion of the temporal bone, and the anterior aspect of the petrous portion. The superior border of the petrous makes an indentation on the inferior aspect of this lobe, which marks the boundary between the temporal and the occipital lobes. It is most important to state these anatomical details with exactness, because, when dealing with a living subject, there is always a tendency to locate the temporal lobe too high up and too far back. The temporal pole really lies behind the orbit, and throughout the greater part of their

extent the convolutions on the external aspect of the lobe correspond to the bony wall above the zygomatic arch, and above and in front of the external auditory meatus. It is most necessary to bear these details in mind if it is desired to locate quickly the site of a wound of the temporal lobe without making a serious error.

There are five temporal convolutions :—

The first convolution, or superior temporal gyrus, is slightly sinuous and rather thin, forming the inferior lip of the Sylvian fissure, at the superior extremity of which it unites with the second parietal to form the gyrus supramarginalis.

The second convolution, or middle temporal gyrus, is parallel to the first convolution, from which it is divided by the extremely deep first temporal or parallel sulcus. At its posterior extremity this convolution bifurcates, the upper branch uniting with the second parietal to form the angular gyrus, while the lower one is continuous with the third occipital convolution.

The third convolution, or inferior temporal gyrus, forms the inferior border of the external aspect of the lobe. At its posterior extremity it terminates at the pre-occipital notch.

The fourth convolution is situated on the inferior aspect of the lobe. It is narrow at its anterior extremity, but widens gradually till it unites directly with the fourth occipital convolution to form the fusiform lobule.

The fifth convolution, or hippocampal convolution, is divided from the fourth by the deep fourth temporal (collateral) sulcus. It occupies the internal border of the inferior aspect of the lobe. Its tapering posterior extremity unites with the fifth occipital convolution or lingual lobe. The anterior third of this convolution laps over and conceals the optic

tract, which it presses on to the cerebral peduncle (crura cerebri).

Attached to the fifth temporal convolution are a series of anatomical structures: the hippocampus major with its fimbria, the tænia hippocampi, the sulcus of the hippocampus, and the amygdaloid nucleus, with which it is not necessary to deal.

It is important to be acquainted with the fibres of the white matter of the temporal lobe. The association-fibres include the arcuate fibres connecting one convolution to another; the superior longitudinal fasciculus; the uncinate fasciculus extending from the frontal to the temporal lobe; the inferior longitudinal fibres which extend from the temporal to the occipital lobe. This bundle covers a most important projection strand—the optic radiation—which starts from the corpus geniculatum externum below and outside the optic thalamus.

Physiology

The generally accepted theory supposes the temporal lobe to be essentially the site of the auditory centre.

According to Meynert, the acoustic fibres converge on the insula and on the superior temporal convolution. It is interesting to remember that Wernicke, relying on these data, located the auditory centre in the superior temporal gyrus, and, as Professor Pierre Marie has pointed out, it was by starting with this improved view that Wernicke was led to the discovery of a new type of aphasia arising from lesion of the parieto-temporal lobe. Experimental research has given very contradictory results. Munk, after a long course of experiments on the dog, claimed to have located the auditory centre in the temporal lobe, and described a psychic and a cortical deafness and a localisation of sounds according to their pitch. The

auditory area on each side was supposed to be in relation with the labyrinth on the opposite side. The results of these experiments were entirely contradicted by those of Kalischer on specially prepared dogs, from which he had removed both temporal lobes; these animals proved to be absolutely normal in the perception of sounds, however high their pitch. Therefore nothing, or next to nothing, is known of the functions of the temporal lobe, and there is not the slightest verification of the accepted theory that the auditory centre is located in this lobe.

Symptoms

Most of the symptoms described by the classic writers as arising from lesion of the temporal convolutions have no clinical existence. The symptoms actually found do not really arise in the temporal lobe. The real explanation of the clinical picture is that there is either simultaneous lesion of the adjacent regions of the parietal lobe, or a deep-seated injury of the white fibres or of the grey nuclei.

A. Symptoms of superficial wounds of the temporal lobe.—The classic writers describe the following symptoms as occurring in the human subject in consequence of a lesion of the temporal lobe :—

1. *Cortical deafness.*—This view is based on the anatomical conclusions of Meynert, mentioned above. According to this theory, there was in the brain in the region of the temporal lobe a general auditory centre lesion which causes an ordinary deafness similar to that produced by disorders of the functions of the peripheral apparatus. Up to now there has not been a single clinical case with anatomical verification of deafness of cortical origin.

2. *Pure word-deafness.*—The same theory describes a verbal auditory centre in the foot of the first temporal

convolution, where the auditory images of words, syllables, and letters are stored up. Bilateral lesion of this centre, or a lesion of the centre in the left hemisphere alone, was supposed to give a special syndrome: pure word-deafness characterised clinically by the fact that while the patient does not

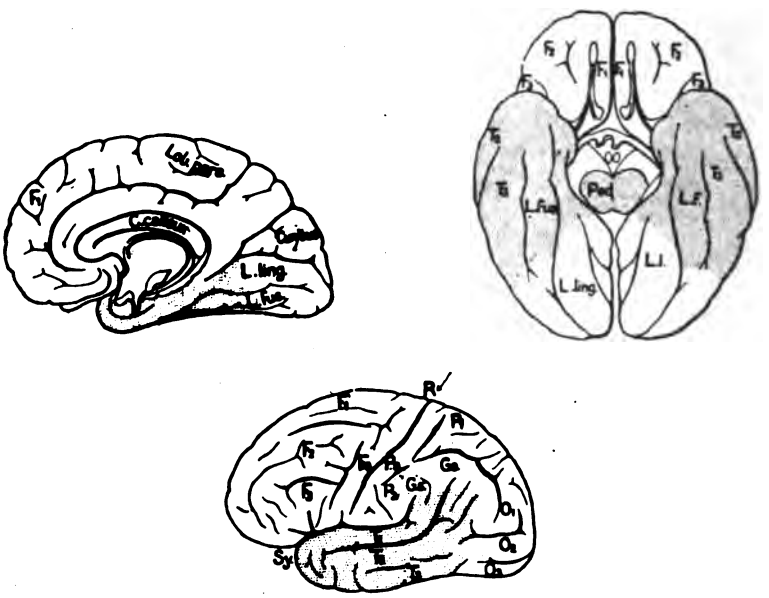


FIG. 14.—External and internal aspects of one hemisphere and inferior aspect of the brain.

The convolutions are marked by a letter with an indicator: F_1, first front ; Fa, ascending frontal, etc.; Gs, gyrus supramarginalis; Ga, gyrus angularis; R, fissure of Rolando; Sy, Sylvian fissure; Lob. para, paracentral lobule; L. ling, lingual lobule; L. fus, fusiform lobule, etc.

understand a word of what is said to him aloud, he shows no other disorder, and consequently he is unable to repeat what was said to him or to write from dictation. As a matter of fact, as has been shown by Professor Pierre Marie, not a single case of pure word-deafness has been observed clinically, and the

anatomical and pathological descriptions which have been published are extremely misleading; both with regard to cortical deafness and pure word-deafness, not a single case has been observed among the patients wounded in the temporal region which supports the existence of these two syndromes. The clinical picture of pure word-deafness and its anatomical localisation are purely theoretical conceptions.

8. *Wernicke's aphasia or sensory aphasia.*—It is quite otherwise with regard to the part which the posterior portion of the two first temporal convolutions in the left hemisphere plays in the human being. This temporal region forms a part of Wernicke's zone, which also includes the gyrus angularis and the gyrus supramarginalis, with the subjacent white matter in all the convolutions. Lesion of this "zone of Wernicke" causes aphasia of the so-called sensory type or "Wernicke's aphasia," a syndrome which appears as soon as there is the slightest lesion of this area, its intensity being in proportion to the extent of the lesion of Wernicke's zone or of the fibres which proceed from it. This is a typical example of the law established by Professor Pierre Marie regarding the pyramidal tract—that a complete cerebral hemisyndrome is produced by the lesion of a part only of the zone in which it takes its rise. There is nothing to authorise the breaking up of this "Wernicke's zone" into separate centres controlling special departments of the function of language as was done by the older authorities. The "zone of Wernicke" has been shown by Professor Pierre Marie to be, above all, the intellectual centre of language controlling the comprehension of speech, of reading and of writing, the lesion of which causes true aphasia, which includes a variety of clinical types, and has the following clinical characters: the patient can speak, indeed he often speaks too much, but indistinctly; he presents

jargonaphasia, or at the least paraphasia; he does not understand well what is said to him, and he is unable to read or write. A special chapter will be devoted to the very important subject of aphasia, and the special clinical aspects of aphasic disorders in cases of wounds of the brain, as shown by the researches of MM. Pierre Marie and Charles Foix, will be described. At present no symptoms are known which prove superficial lesion of the temporal convolutions except the posterior portion of the first and second left temporal convolutions (Wernicke's aphasia of variable intensity).

B. Symptoms of deep wounds of the temporal lobe.—As the result of wounds in the temporal region a whole group of symptoms may be found from which it may be inferred that there is a deeply penetrating lesion of the white matter, which in some cases may extend to the grey central nuclei (the lenticular nucleus and the optic thalamus). It must be stated, however, that such complications are rare, because, owing to the extreme gravity of the wound, which is almost certain to injure the lateral ventricle, or to be associated with lesions of the medulla through concussion or contusion, it is quickly fatal.

1. *Lesions of the grey central nuclei (optic thalamus) and of the cerebral peduncles.*—The whole of the group of symptoms described in recent years under the names of thalamic or lenticular syndromes are not met with in war-wounds, but merely a few of the symptoms of which they are made up. The only indications which have been observed are hemiataxia, with marked disorders of the deep sensation associated with slight hemiparesis. These symptoms, viz. hemiataxia, hemianæsthesia (involving specially the varieties of deep sensation), and slight hemiplegia, are parts of the thalamic syndrome of Dejerine and Roussy, which also includes intense pain in the whole

of the side of the body affected by the anæsthesia, and hemichorea with hemiathetosis. No case has ever been observed where there was good reason to suppose, as some writers have done, that there was injury of the cerebral peduncle at its point of contact with the fifth temporal convolution (see Anatomy), which would be manifested by crossed hemiplegia with direct paralysis of the third pair or oculomotor nerves (Weber's syndrome).

As has already been stated, injury of the oculomotor nerves can seldom be used in wounds of the brain as a means of localisation. Total or partial paralysis of the third nerve, as well as paralysis of the sixth, is fairly frequent as a complication of wounds of the temporal region, and is caused, probably, by extension of a fracture to the base of the skull, in the same way as paralysis of the eighth nerve, which is a common complication of wounds in the same region, and will be dealt with later.

2. *Lesions of the white fibres* (*optic radiation and optic tract*).—Penetrating wounds of the temporal lobe are frequently accompanied by hemiopic modifications of the field of vision, which are connected with either direct lesion of the optic radiation in the depth of the lobe, or to an affection of these fibres at their point of contact with the seat of traumatic encephalitis. Homonymous lateral hemiopia, such as is produced by deeply penetrating wounds of the external aspect of the occipital lobe, is most frequently observed. In other cases there may be incomplete lateral hemiopia, predominantly in the superior or inferior quadrant of the field of vision, or a lateral homonymous hemiopic diminution thereof, complemented by hemiachromatopia. This very curious modification of the field of vision will be dealt with in detail, together with the other visual disorders, in the chapter on "Wounds of the Occipital Lobe" (Chapter

VIII.). As a matter of curiosity the case of homonymous lateral hemiopia through lesion of the optic tract, of which the author has published a description in collaboration with Professor Pierre Marie, may be mentioned here.[1] A very small missile after traversing the anterior portion of the right temporal lobe injured the optic tract at its point of contact with the cerebral peduncle and produced homonymous lateral hemiopia on the left side.

Complications

The only important complication, and a very frequent one, of wounds of the temporal region, is lesion of the auditory apparatus on the same side as the wound.

The examination of this organ must never be neglected, though the patient himself will generally call attention to the fact that he can only hear badly, or is quite deaf, in the ear on the wounded side. There may be merely laceration of the tympanum, which is easily proved by examination with the otoscope. Much oftener, however, there is more or less serious lesion of the internal ear, caused either by direct injury of the main body of the petrous process across the temporal lobe, or by extension of a fracture. In such cases, as a rule, there is complete peripheral facial paralysis on the same side as the deafness. It is for the aurist to deal with deafness caused by lesions of the internal ear, but the neurologist ought to be qualified to ascertain definitely, to a certain extent, whether the lesion affects the organ of reception or the organ of transmission. Reference should be

[1] "A case of traumatic homonymous lateral hemiopia on the left side through lesion of the right optic tract," by Professor Pierre Marie and Dr Ch. Chatelin. (*Revue Neurologique*, Nos. 23–24, p. 1230, 1915.)

made to the section of Chapter I. dealing with the auditory tests.

Much more important to the neurologist are the lesions of the vestibule of the labyrinth, which may occur alone without any auditory symptoms caused by lesion of the cochlea. The patient has subjective disorders (vertigo, nausea, sense of falling, and lateropulsion) and objective disorders of equilibrium while at rest and while walking, which should be most carefully examined and tested, especially if he has no disorders of hearing, in which case it is necessary to ascertain whether there is a lesion of the cerebellum, the differential diagnosis being often extremely difficult. This subject will be dealt with in detail in the chapter on " Wounds of the Cerebellum " (Chapter IX.). Cases of paralysis of the third and sixth nerves have been dealt with above.

Course and Prognosis

The course and prognosis of wounds of the temporal lobe depend on the site of the wound and the complications.

The prognosis of wounds of the posterior third of the first temporal convolution on the left side, accompanied by Wernicke's aphasia, must be very cautious with regard to the intellectual future of the patient (see Chapter VII.), the aphasia being in some degree proportionate to the extent of the cerebral lesion. Complete labyrinthine deafness is generally permanent; on the other hand, the disorders caused by injury of the vestibule of the labyrinth (vertigo, disorders of equilibrium and gait) generally improve gradually, and disappear in less than a year after the infliction of the wound.

CHAPTER VII

APHASIA IN RELATION TO WOUNDS OF THE BRAIN

Introductory remarks on Aphasia

BEFORE entering upon the consideration of the disorders of speech, more especially those of the aphasic type, it will be well to state as concisely and clearly as possible the old accepted theory of aphasia, and Pierre Marie's new conception thereof.

The history of aphasia begins with Broca, who localised the faculty of articulate language in the foot of the third left frontal convolution, and proposed to call the loss of this function aphemia. The name aphasia was given by Trousseau.

Wernicke showed that in aphasia the loss of articulate language was not the only thing, and distinguished aphasic subjects whose motor functions were solely or chiefly affected, from those who were incapable of identifying verbal auditory impressions. In this form of aphasia, called sensory aphasia, the fundamental disorder, according to Wernicke, was that of hearing, which entailed difficulties of reading and writing as a consequence, the patient being unable to understand the words which fell on his ears, while the power of articulate language was retained. Wernicke located this form of aphasia in the first temporal convolution on the left side.

The accepted theory of aphasia.—Under the influence of these psychological ideas the varieties of aphasia increased, and two great classes of aphasics were distinguished: those who suffered from disorders of articulation, and those who suffered from internal derangement of speech and the comprehension of speech. The first class, who were said to suffer from motor aphasia, had lost the motor images of articulation. The second class, who were said to suffer from sensory aphasia, had lost the auditory visual sensory images of words, which are located in various centres on the left side of the brain; the foot of the third frontal convolution for motor images, and the first temporal and gyrus angularis for the sensory images (auditory and visual). These centres might be injured directly or in their channels of transmission, whence they were divided into the cortical and sub-cortical varieties of aphasia.

In practice six forms of aphasia were described:—

1. *True motor, or Broca's aphasia.*—The patient could not articulate, or did so badly; he had great difficulty in writing, but could copy printed words in his ordinary handwriting; there was also difficulty in the comprehension of spoken language and of written words, but this was not usually great. The anatomical cause was lesion of the cortex of the foot of the third frontal convolution.

2. *Sub-cortical, or pure motor aphasia,* was distinguished from the others by suppression or diminution of the power of speech, and was attributed to section of the nerve-fibres which proceed from Broca's centre.

3. *Sensory, or Wernicke's aphasia.*—The patient could speak, and often spoke a great deal, but used one word in mistake for another (paraphasia), or spoke words without meaning (jargonaphasia); he had great difficulty in understanding spoken words (word-deafness) or written words (word-blindness), and he could

not write. This form of aphasia was said to be caused by destruction of the two first temporal convolutions, the gyrus supramarginalis and the gyrus angularis.

4. *Pure word-deafness.*—The patient could not understand words spoken aloud, nor repeat them nor write from dictation; but he could speak perfectly, and the power of reading aloud or silently was unimpaired. This word-deafness was supposed to be due to lesion of the two temporal lobes.

5. *Pure word-blindness.*—The patient could not read (alexia), he could speak perfectly, and writing spontaneously and from dictation were normal, but he could not read what he had written, although his intelligence was unimpaired. This form of aphasia was supposed to be caused by lesion of the gyrus angularis.

6. *Total aphasia* was a combination of motor and sensory aphasia; the patient could neither speak, nor read, nor write, nor understand signs.

Pierre Marie's theory of aphasia.—Professor Pierre Marie has enunciated a new theory, and has opposed on anatomical and clinical grounds the specific character of Broca's centre; the distinction between motor and sensory aphasia; the existence of pure forms of aphasia; and the whole idea of images and centres of images. In Pierre Marie's opinion, one fact dominates the whole question of aphasia—the more or less strongly pronounced inability to understand spoken language. Though certain writers claim that the intelligence remains intact, as a matter of fact there is a very marked diminution of the general intellectual capacity in aphasic patients, which is a much more serious matter than the mere loss of the power of understanding words. In fact, if an aphasic subject is methodically examined, it will be found that he has not only lost the power of language, but that there is a considerable deficiency in the stock of knowledge

acquired didactically. It is this intellectual decay, and not the loss of supposed verbal auditory images, or the existence of word-deafness, which is the essence of the aphasia. Again, it is not the mere fact of speaking badly or of not being able to speak at all which constitutes true aphasia. This disorder, which was classically named sub-cortical motor aphasia, must be carefully distinguished from aphasia, and described separately as anarthria or dysarthria. The outstanding characteristic of Pierre Marie's anarthria is, that while the patient can hardly speak, or does so only with great difficulty, he can understand thoroughly what is said to him, and can read and write perfectly.

Clinically, Broca's aphasia and Wernicke's aphasia are real conditions, but they are very analogous, and are only separated by a few degrees from each other. The only difference, which is, however, an essential one, between the two aphasias is, that in Wernicke's the patient can speak, and often speaks a great deal, and in Broca's he cannot speak, or speaks very little; in short, Broca's aphasia differs from Wernicke's by the addition of anarthria. In Wernicke's aphasia the patient can speak, but fails to understand what is said to him, and can neither read nor write. In Broca's aphasia the patient can neither read nor write, he fails to understand what is said to him, but in addition he speaks with great difficulty or not at all; he has both aphasia and anarthria.

With regard to cerebral localisation, there is a whole series of anatomical and clinical observations to support the contention that the third frontal convolution is not the speech centre. On the contrary, in every case of anarthria there is an isolated lesion of the lenticular area of the brain defined by Pierre Marie, which includes the central grey nuclei and the internal and external capsules, the insula, the motor cortex, and some important fibres of the white matter,

while the third frontal convolution is not included. Anarthria is not connected solely with the left side of the brain, but occurs also through lesion of the same lenticular area on the right side.

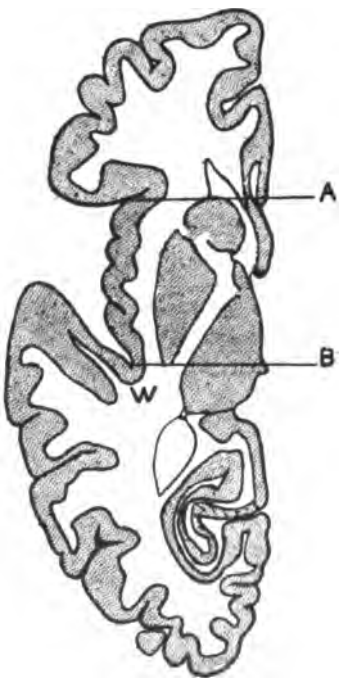


FIG. 15.—Horizontal section of a healthy left hemisphere intended to show the topography of the areas, the lesions of which give rise to troubles of speech, or, on the contrary, have no part in the production of them (after Pierre Marie).

Lesions occurring in the portions of the hemisphere (the frontal lobe, and notably the third frontal convolution) situated in front of the transverse line A, which is drawn from the sulcus separating the third frontal from the convolutions of the insula, produce neither anarthria nor aphasia.

Lesions bearing on the region situated between A and B (Pierre Marie's lenticular zone) give rise to anarthria. The line B is drawn transversely from the posterior part of the insula and the posterior extremity of the lenticular nucleus. Lesions situated in rear of B cause aphasia.

In W (Wernicke's zone) is the isthmus of white matter which unites the temporo-parietal lobe to the lenticular nucleus.

As far as aphasia is concerned, since there is only one kind of aphasia, it is located solely in Wernicke's zone, which includes the gyrus supramarginalis, the gyrus angularis, the foot of the two first temporal convolutions, and the subjacent white matter up to the wall of the sphenoidal horn of the lateral ventricle, which is in direct contact in front with the lenticular area above described (the temporo-parietal isthmus of Pierre Marie). In cases of Wernicke's aphasia it is a lesion, variable in extent, of this region which is found. In Broca's aphasia, which is Wernicke's aphasia plus anarthria, there will therefore be found a lesion of Wernicke's zone plus a lesion of the lenticular area. It will be seen how infinite may be the clinical varieties according as one zone or the other is the more extensively involved in the lesion.

To sum up. According to Pierre Marie, " the third frontal convolution plays no special part in the function of speech." The true centre of speech is Wernicke's zone, which must be considered to be an intellectual centre and not a sensory centre. In proportion to its extent, any lesion of this centre produces, besides the disorder of speech, a falling-off in the understanding of spoken language and of the power of reading and writing, as well as the loss of certain classes of didactic ideas.

Anarthria is clinically characterised by the loss of speech, while the comprehension of words heard is retained, together with the capacity to read and write, and is produced by a lesion situated in the lenticular area, which impedes the co-ordination of the movements required for the production and articulation of words without producing true paralysis of the muscles.

Wernicke's aphasia is produced by a lesion of Wernicke's zone. Broca's aphasia is produced by the combination of the lesion of anarthria in variable

proportion, according to the case, with a lesion of Wernicke's zone; thus Broca's aphasia = Wernicke's aphasia + anarthria.

Pure word-deafness has no clinical existence. Pure word-blindness, or, to be exact, pure alexia, does exist, but is not localised solely in the cortex of the gyrus angularis (see Chapter VIII., "Wounds of the Occipital Lobe").

This conception, which differs so greatly from the accepted theory, and is founded entirely on direct investigation of the experience of civil practice (namely, of lesions caused by softening of the brain), has been confirmed by the study of wounds of the brain, as will be seen later on.

Technique of the Examination in a case of Aphasia

The following is a concise outline of the method in which the examination of an aphasic patient is carried out by the staff of Professor Marie at the Salpêtrière which will be useful as a guide in carrying out such examinations, which must be done methodically:—

1. Test for Comprehension of Speech

(*a*) *Tell the patient to perform the following simple actions:* Put out his tongue, shut his eyes, knock at the door, shake hands, seal up a letter, light a cigarette.

(*b*) Perform any of these actions which the patient has failed to carry out, and tell him to copy you.

(*c*) Give the patient instructions containing the same word but for different actions: To shake hands, clasp hands, raise the hand, open and shut the hand.

(*d*) Give him a complicated instruction —

1. "Here are three pieces of paper on the table, one large, one medium-sized, and one small; pick up the large one and hand it to me, tear up the medium

sized one and throw the pieces on the ground, and keep the small one in your hand."

2. "Get up, go and knock at the door three times, and return to your seat."

2. Examination of Speech

(*a*) *Spontaneous speech.*—Does it exist, and to what extent? Hand the patient some objects, and tell him to name them; tell him to pronounce words in series, as: the days of the week, the months of the year; the alphabet, the numbers from one to twenty; to repeat these series of words backwards. Tell the patient to describe how he was wounded. Tell him to state his profession. Note whether during this examination there is any dysarthria, paraphasia, or jargonaphasia.

(*b*) *Repetition of words.*—Speak to the patient in phrases of gradually increasing length and difficulty, and make him repeat them; make him repeat words beginning with the same syllable, as: tart, tartar, tartuffe, tartlet, etc. Make him repeat some lines of poetry.

(*c*) *Singing.*—Can the patient sing with or without words? Can he repeat a song? Can he shout, whistle, cough, etc.?

3. Examination for Reading

Make the patient read aloud. Is silent reading possible? Give him a simple written order to execute, such as: shake hands, put out the tongue. Give him a more complex order. If he cannot read words, get him to name single letters and numbers. Hand him a book or paper upside down, and see whether he puts it in the correct position. Make him read words written vertically. Make him state the meaning of a drawing or emblem. Get him to pick out a word

designating one object placed among others, to tell the time by a watch, to set the watch to a given time; to read figures and make elementary calculations; to count money.

4. Examination of Writing

(*a*) Can he write spontaneously with pen, or pencil, or blocks ?

(*b*) Can he write from dictation ?

(*c*) Can he copy printed letters, in print ? in long hand ? Can he do the same with figures ?

(*d*) Can he make a simple drawing : a square, triangle, oblong, etc. ? Get him to copy them.

5. Power of Mimicry

(*a*) *Spontaneous mimicry of emotions.*—Tell the patient to make a gesture indicating dislike, to shake his finger at someone, to throw a kiss.

(*b*) *Spontaneous descriptive mimicry.*—To make signs that he wishes to sleep, to imitate the action of leading a horse.

(*c*) *Conventional mimetic signs.*—Make the sign of agreement or of disagreement. Does the patient understand the meaning of gestures ?

6. Condition of the Memory

General memory.—For dates, facts, the multiplication table.

Visual memory.—For persons, places (sense of location), objects. What does the wind do to the dust ? In the branches of trees ? In the sails of ships ? How many legs has a dog ? What is the colour of snow ? of grass ? of blood ?

Auditory memory.—What does the cock do ? the cat ? the horse ? the dog ? the railway engine ? the

bell? The observer says things wrongly to see whether the patient will correct him.

Memory of tastes.—It must be thoroughly understood that this special examination is always to be supplemented by a general examination of the nervous system, particularly of the motor functions for hemiplegia; of sensation for astereognosis; of the auditory functions for labyrinthine deafness; and of the visual functions for hemiopia and hemiachromatopia. And care must always be taken to ascertain whether the patient is right-handed or left-handed.

Aphasia consequent on Wounds of the Brain

The Wound

The disorders of speech will be dealt with according to the site and extent of the wound. This is the best division of the subject in view of the great number of clinical variations, and it will also demonstrate more clearly the correctness of the new theory of aphasia expounded above.

In a large majority of cases the aphasic disorders, or the disorders of speech, arise from wounds inflicted by a bullet or shell-splinter which have necessitated trephining. In some cases, however, the aphasia has been caused by direct contusion of the left hemisphere through a fall or by shock caused by explosion at a distance.

It is important to note that, in certain cases in which the lesion was in the right temporo-parietal lobe, the disturbances were slight, and were almost entirely confined to dysarthria, associated with some degree of obnubilation, a condition which is of little importance, and may persist for a variable time in any case of a head wound. If the wound affects the left side of the brain, disorders of speech are the rule; at any rate, they persist for a variable time during the course of

the case, and behave differently according to the site of the cerebral lesion.

Aphasic Troubles in relation to the Site of the Wound

The following paragraphs are a summary of the clinical and radiographic researches carried out by

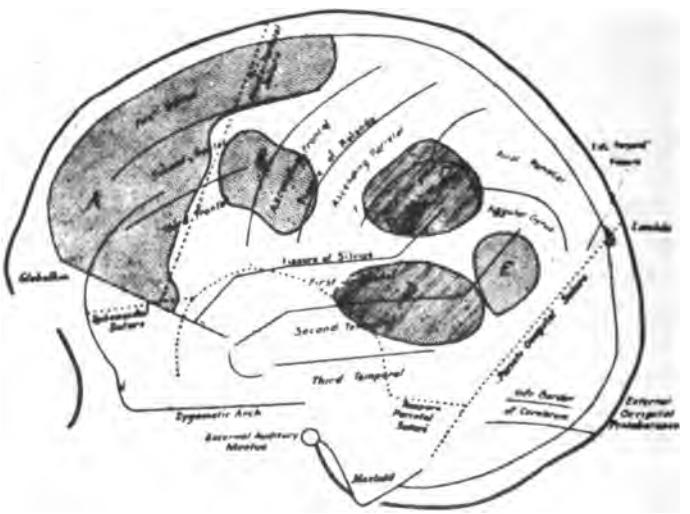


Fig. 16.—Radiographic localisation of wounds of the skull, with the subjacent lesions which cause the different varieties of troubles of speech (Pierre Marie, Ch. Foix, and Bertrand).

A, zone without troubles of speech; B, dysarthria or anarthria; C, complete aphasia; D, aphasia, predominant in denomination of objects; E, predominant alexia.

MM. Pierre Marie and Ch. Foix at the neurological centre at the Salpêtrière, which will be the subject of an important work by these writers.[1]

[1] A communication on this subject has been made to the combined session of the Societe National de Chirurgie and the Societe de Neurologie de Paris on the 24th May 1916, by M. Ch. Foix, from which the data given in this chapter are borrowed. (*Revue Neurologique*, No. 6, 1916, p. 827.)

Wounds of the central region: the ascending frontal and ascending parietal convolutions.—If the wound is in the superior portion of the convolutions near the paracentral lobule there is usually no trouble with speech; most frequently the patient has a crural monoplegia. Wounds of the median portion of the central convolutions produce, as we have seen, a brachial monoplegia. If there are any disorders of speech, they are slight. A minute examination of the powers of reading, writing, and calculation only shows very slight deficiency, which is more marked when the wound implicates the ascending parietal, in which case there will be sensory disorders associated with monoplegia, and also a certain degree of dysarthria. Syndromes of anarthria, very severe at first, and leaving persistent dysarthria subsequently, are connected with the inferior portion of the central region. The further forward the site of the wound, the more pure is the anæsthesia. If a wound of the rolandic area extends into the centrum ovale or still lower, the aphasia affects the whole range of the functions of language—reading, writing, comprehension of speech, articulation, and calculation. The lower and more deeply penetrating the wound, the more pronounced are these disorders. The syndrome in such cases is that of Broca's aphasia, which may be of a very severe type, and only capable of very limited cure.

Wounds of the temporo-parietal region.—With the exception of the extreme upper part of the parietal lobe and the anterior part of the temporal, lesions of which cause only slight disorders, wounds of the temporo-parietal lobe give rise to syndromes of true dissociated aphasia. At the outset there is complete inability to speak, which generally continues for some weeks; then the power of speech gradually returns, together with the ability to understand speech; finally, the power of reading and writing is also

recovered to a certain extent. The development of the symptoms generally lasts several months, and the syndrome is generally fixed at the end of six or eight months. At this stage several clinical types can be distinguished :—

(*a*) *The syndrome of aphasia* (*Wernicke's type*).—The patient shows little dysarthria, but principally inability, often pronounced, to name objects; the disorders of the intellect are strongly marked, and the power of calculation is always greatly diminished. It is important to note that the most marked and most persistent syndromes of aphasia arise much more frequently from wounds of the middle and posterior temporal regions than from a lesion of the gyrus angularis or the gyrus supramarginalis.

(*b*) *The syndrome of total aphasia.*—All the elements of speech are almost equally affected. The anarthric symptoms are as pronounced as the strictly aphasic ones. A mild brachial monoplegia is often associated with this condition. The lesion is situated in the region of the gyrus supramarginalis.

(*c*) *Predominant alexia* is observed in wounds of the extreme posterior end of the temporo-parietal region, which, if deep enough, are associated with homonymous lateral hemiopia or quadrantic hemiopia. If the wound is plainly occipital there will be no defect in the power of reading, even though there may be marked diminution of the field of vision, provided that the lesion does not penetrate very deeply, and does not injure the white fibres of the cortex of the temporo-parietal lobe.

(*d*) *Aphasic residuum.*—The intellectual defect is principally in the power of calculation and the vocabulary, which is very limited, the patient having to search for a long time for the right word to designate an object. The patient is able to read pretty well, but not to understand what he has read. It is

generally easy to detect these troubles, but they must be methodically sought for, because a knowledge of their existence is important.

Wounds of the posterior frontal region.—When the lesion involves the area including the foot of the left external frontal convolutions and the inferior portion of the ascending frontal it is frequently associated with disorders of speech, especially if the lesion is low down and far back. These disorders are generally absent if the lesion is slight, but present when the lesion is deep, and are then generally associated with hemiplegia. The clinical aspect is as follows: Immediately after the wound there is complete, or nearly complete, anarthria, and a hemiplegia (which disappears in some hours or not for some weeks), and there is difficulty in reading. When speech is regained, as it generally is after a variable period, the disorders diminish rapidly, and there remains only a slight dysarthria, which affects the intonation, the utterance, and the articulation all at the same time, and which gradually disappears. The power of writing is unaffected, but there is often difficulty in reading. Complete, or nearly complete, cure is the rule.

Wounds of the pre-frontal region, whether situated on the right or on the left side, do not give rise to disorders of speech, except that just at first there may be slight and very transient dysarthria, sometimes of a special type (such as faltering or great deliberation of speech).

Course and Prognosis

Wounds of the left anterior frontal region do not cause disorders of speech. Wounds of the left frontal region are associated with transitory anarthria, followed generally by complete cure. Wounds of the rolandic area are associated with monoplegia or

hemiplegia. When the lesion is superficial and affects principally the inferior portion of the ascending frontal there will be anarthria, leaving behind it a rather prolonged dysarthria. When the lesion is deeper there will be Broca's aphasia, the more strongly marked the lower and more deeply penetrating is the lesion; this aphasia is usually but little susceptible of cure. Wounds of the temporo-parietal region produce an aphasia closely resembling Wernicke's, and cause grave and lasting diminution of intelligence and of the power of speech. These details of prognosis are of great importance, because most of the patients remain permanent invalids. Although their complaints appear to be trifling, methodical clinical examination will discover a very great diminution of the capacity of these men for useful employment, and the almost complete impossibility of any of them returning to their trades.

Differential Diagnosis

The clinical aspect of aphasic disorders is too characteristic for it to be possible to make any error of diagnosis. But it is necessary to observe that there are dysarthric disorders which are not due to lesion of the lenticular area.

Cerebellar dysarthria is characterised by a very deliberate, explosive, sometimes wandering or drawling method of speaking.

Pseudo-bulbar dysarthria occurs in lesions of the central grey nuclei or of the pons. The patient speaks breathlessly, and his speech is nasal, muffled, and choking. There is a whole range of symptoms that point to the seat of the lesion: bilateral hemiplegia, dysphagia, and spasmodic laughter and weeping.

Bulbar dysarthria is due to nuclear paralysis, and is marked by amyotrophia and fibrillar tremors of

the muscles, innervated by the seventh and twelfth pairs of nerves. As far as is known, none of these varieties of dysarthria are caused by a direct blow, but nearly always by "contre-coup" or by concussion, as will be described later.

Aphonia, mutism, or hysterical deaf-mutism, which frequently occur in wounded patients, are too easy of diagnosis for it to be necessary to dwell upon them.

CHAPTER VIII

WOUNDS OF THE OCCIPITAL LOBE

THE essential characteristic of wounds of the occipital lobe is the existence of visual disorders due to lesion of the visual area of the occipital cortex and of the central optic tracts. This group of results is much more common than could possibly have been supposed. Nimier, in his remarkable work on *Gunshot Wounds of the Skull and Brain*, mentions only about ten cases of visual disorders of the hemiopic type, several of which are drawn from civil practice. Tatsuji Inouye, who has devoted an important work to the special study of the visual disorders due to war-wounds of the visual centre of the cortex, has collected only 28 positive cases from among nearly 80,000 wounded in the Russo-Japanese war. On the other hand, out of 1200 wounds of the skull we have examined 300 wounds of the occipital region, and have found 85 cases in which there was alteration in the field of vision, sometimes associated with other symptoms. This will give some idea of the extreme frequency of these disorders, since they appear in 7 per cent. of the cases of wounds of the skull. We shall see that in many patients these alterations in vision are overlooked because they are not associated with persistent subjective disorders.

Anatomy and Physiology

In many cases wounds of the occipital lobe are not accompanied by any appreciable symptoms. The occurrence and character of the visual disorders are closely related to the anatomy of this part of the brain, which is briefly described in the following paragraphs giving the anatomical and physiological data necessary for a clear explanation.

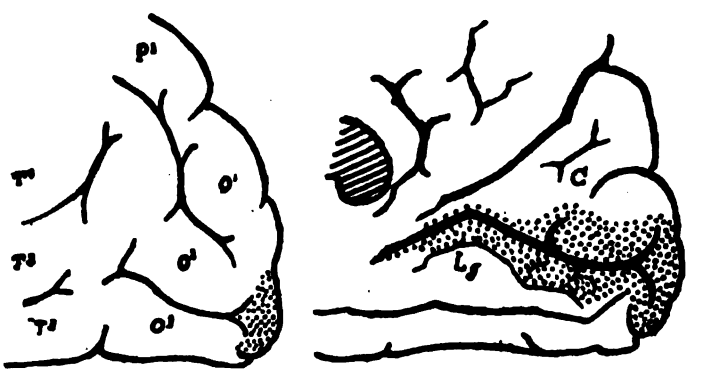


FIG. 17.—The area striata according to Brodmann.

External aspect of the occipital lobe.	Internal surface of the occipital lobe.
O^1, O^2, O^3, occipital convolutions.	C, cuneus.
T^1, T^2, T^3, temporal convolutions.	Lg, Lingual lobe.
P. O. F., parieto-occipital fissure.	
P. O. S., parieto-occipital sulcus.	

The extent of the area striata round the calcarine fissure is shown by the dotted area.

Anatomy.—The occipital lobe in shape somewhat resembles a pyramid; the base is in front, and is joined on to the rest of the hemisphere; the summit is the posterior extremity of the lobe, or occipital pole, and lies beneath the upper and outer part of the internal occipital protuberance. The external aspect corresponds to the concavity of the occipital bone,

and is made up of three convolutions (the first, second, and third occipital) placed horizontally, and converging towards the point of the lobe. The inferior aspect is slightly concave, and inclined downwards and outwards; it is made up of two convolutions, the fusiform lobule without, and the lingual lobe within. The tentorium cerebelli is interposed between it and the upper surface of the corresponding lobe of the cerebellum. The internal aspect is divided from the lobe on the opposite side by the falx cerebri, and consists entirely of the triangular sixth occipital convolution, the cuneus; its summit is anterior; the superior border is marked by the parieto-occipital or internal perpendicular fissure, and the inferior border by the calcarine fissure. This extremely deep fissure is situated at the lowest part of the internal aspect of the occipital lobe, and extends upwards and forwards from the point of that lobe towards the hinder end of the corpus callosum.

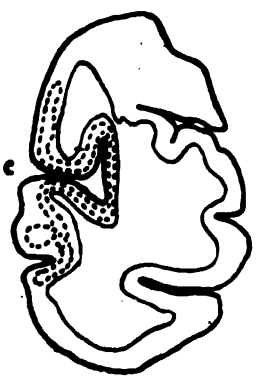


FIG. 18.—Vertico-transversal section of the occipital lobe behind the point of the ventricle. c, calcarine fissure. The dotted line shows the extent of the area striata.

The white matter of the occipital lobe is traversed by the bundle of fibres which form Gratiolet's optic radiations, the lowest and most external portion of which forms the inferior longitudinal fasciculus. This fasciculus extends from the corpus geniculatum externum to the internal aspect of the occipital lobe, and passing above the horn of the lateral ventricle is spread out round the calcarine fissure, and is known as the intra-cerebral optic fasciculus.

Localisation of the visual area.—While some authors

attribute to the visual centre an area covering the whole of the cortex of the occipital lobe, including its external aspect, others confine the function of vision exclusively to the internal aspect of the lobe, and especially to the cortex of the calcarine fissure,

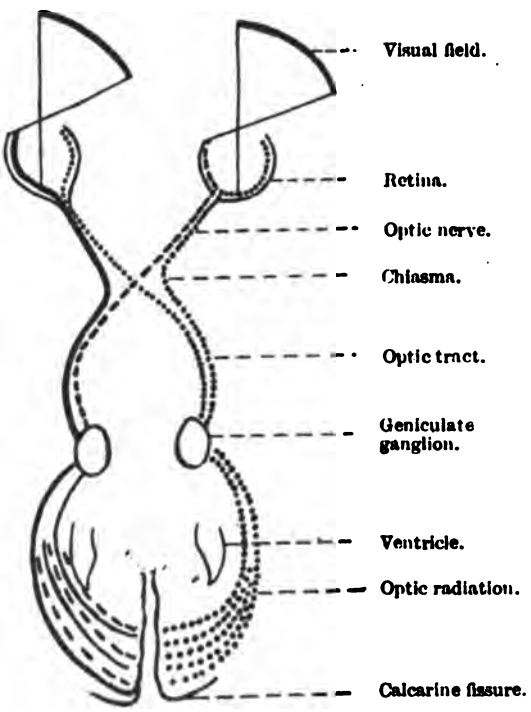


FIG. 19.—Diagram of the optic paths from the calcarine cortex to the retina.

which has indeed a very peculiar type of cellular architecture found nowhere else except in this situation and its immediate neighbourhood. It has received the name of area striata (fig. 17). This area encroaches very slightly on the convex surface of the occipital lobe at the posterior extremity of the calcarine fissure, where it turns round the point of the lobe. This localisation has been confirmed by the

anatomical and clinical researches of Henschen, and seems to be fully justified. Visual disorders in brain injuries are therefore due to injury of this visual centre, or of the fibres which proceed thither. A wound merely involving the external convolutions without penetrating deeply into the lobe will not be marked by any really reliable symptom.

Physiology of the visual area.—It is absolutely necessary to bear in mind that the visual centre of each eye receives simultaneously the visual impressions received by the temporal portion of the retina on the same side, and by the nasal portion of the retina on the opposite side; consequently the destruction of the visual centre of a single side causes loss of vision in a vertical half of the field of vision of both eyes, or homonymous lateral hemiopia, left or right. That is to say, there will be total loss of vision in the right half (homonymous) of the field of vision of each eye if the lesion is on the left side, and *vice versa*; while partial destruction of the visual centre on one side only will cause a partial but identical loss of vision in each homonymous half of the field of vision of each eye. Further, Henschen's researches have shown that the upper part of the visual centre, for instance, the superior lip of the calcarine fissure on one side, corresponds to the superior quadrant of the retina in each eye, and therefore to the homonymous inferior quadrant of the field of vision of each eye; in other words, the cortex of the calcarine fissure receives a projection from the ocular retina.

Site and Characters of the Wound: Occipital Cranio-cerebral Topography

The above rather complicated, but important, anatomical and physiological details will explain why wounds of the occipital lobe are not always accom-

panied by symptoms, because nothing is known of the function of the external convolutions. On the other hand, they will lead us to expect that the symptomatology of wounds of the occipital lobe will be an essentially visual symptomatology, and that the variations in the deficiencies in the field of vision will be very numerous.

Occipital cranio-cerebral topography.—The relation of the surface of the occipital lobe to the skull can be practically and approximately ascertained as follows: draw a horizontal line passing immediately below the external occipital protuberance and reaching the posterior border of the mastoid on each side. From the two extremities of this line draw lines meeting at the lambda; these will form an isosceles triangle, the centre of the base of which will be the external occipital protuberance. Any penetrating wound of the skull in the area thus marked out will affect the occipital convolutions, but in order to provoke disorders of vision, the more distant the wound is from the occipital protuberance the deeper must it penetrate. Only wounds in the immediate neighbourhood of, and especially above, the external occipital protuberance will cause a disorder of vision if they affect the cortex only. The anatomical and physiological details given above will make it clear that the defects of vision caused by these wounds will, in the great majority

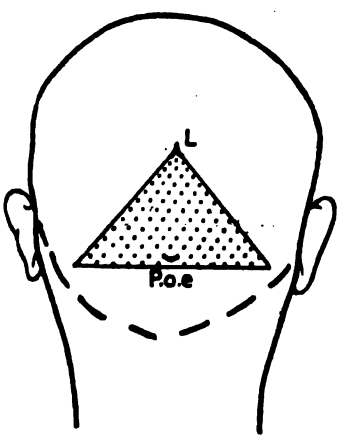


FIG. 20.—Topography of direct occipital wounds accompanied by visual troubles.

L, lambda; P.o.e, external occipital protuberance.

of cases, be situated in the lower half of the field of vision. In fact, in nearly all cases it is the upper half of the visual centre that is affected by such wounds. The inferior lip of the calcarine fissure, deeply situated within the inferior portion of the lobe and in immediate contact with the vermiform process of the cerebellum and the right lateral sinus, cannot be alone affected by wounds, which must nearly always cause simultaneous injury to the cerebellum and the venous sinuses, and will be so grave as to prove fatal. The few cases of injury to the inferior portion of the calcarine fissure alone which have been observed have been caused by indirect wounds. Apart from direct lesions, the occipital lobe may be injured indirectly by missiles penetrating the skull from the parietal or temporal regions, for instance, and becoming arrested in the occipital lobe. It is important to remember this; radiography should always be employed in any case showing alterations in the field of vision, as this will frequently bring to light the presence of a hitherto unsuspected foreign body.

Symptoms

As we have said in our epitome of the present accepted theory of the physiology of the occipital lobe, nothing is known of the functions of its external convolutions, and the symptomatology of wounds of this lobe is confined entirely to the disorders arising from lesion of the visual centre in the cortex or of the central occipital tracts. In the pre-war neuropathology, lesions of the visual centre were usually associated with softening from local arterial degeneration, and then almost the only symptom observed was homonymous lateral hemiopia; cases of quadrantic hemiopia or hemiopic scotoma were extremely rare (Henschen). This difference of symp-

tomatology between lesions of the visual area caused by softening and those caused by war-wounds will be easily understood if it be remembered that in softening the deficiency of cells and nerve fibres is widespread, and involves an entire cone of cerebral matter which is destroyed, while in war cases, when the phenomena of disturbance have ceased and the effusions of blood have been absorbed, the lesion is very circumscribed, of clean section, and situated in healthy cerebral tissue, since the brains are nearly always young, with intact vascular systems and considerable power of repair.

Wounds which penetrate the skull and injure the visual fibres of the cortex, on the other hand, give rise to a great variety of disorders: cortical blindness, inferior hemiopia, single and multiple hemiopic scotomata of all forms, and all these modifications must be methodically looked for with the perimeter, because they are frequently unknown to the patient and his doctor.

Examination of a patient with an occipital wound.—Before beginning to study the varieties of hemiopia it will be useful to sketch out a few points to be observed in the examination of these patients.

It is not necessary to dwell upon the examination of the ocular motility and of the condition of the pupil reflexes, which should always be carried out, nor on the measuring of the visual acuity after correction of any errors of refraction that may be present. The examination of the ocular media and of the fundus must never be neglected, in order to eliminate any corneal or crystalline lesions, and to ascertain the condition of the optic nerve, and especially of the macula. It is essential absolutely to eliminate any macular lesion which might tend to produce a central or pericentral scotoma in the field of vision; such macular lesions are found, as a rule, in the field of vision of one eye only.

These indispensable preliminaries having been carried out, the measuring of the field of vision with the perimeter is proceeded with. This examination should be made by natural light, the patient having his back to the light, and if possible in a room with the walls painted black. A disc of white paper about half an inch in diameter attached to a black index-arm should be used. The patient is told to fix one eye steadily on the fixation point of the perimeter, and the index is displaced by slightly moving it, proceeding from the periphery towards the fixation point. The patient must be strictly cautioned not to move his eye from the point on which it is fixed, and to say immediately he sees a white gleam approaching the fixation point. It will be as well to make one or two preliminary trials so as to make sure that the patient understands the instructions, and to cause the index to disappear behind the perimeter several times so as to see whether the patient becomes aware of its disappearance.

Having taken these precautions, the patient's field of vision is measured by means of the index, which is moved along the circle of the perimeter from the periphery towards the fixation point, changing the inclination of the perimeter round the latter from time to time so as to test a series of meridians. In practice the number of meridians tested should be about ten for each field of vision, and the results should be noted on a diagram made up of concentric circles corresponding to the different degrees of the graduated arc of the perimeter, and crossed with diameters corresponding to the different positions in which the arc of the perimeter can be placed around its zero.

The mapping-out of the limits of the field of vision for colours (red, blue, and green) is conducted in the same way.

It must always be borne in mind that every patient rapidly tires during this examination. The first result of fatigue is an artificial contraction of the field of vision in the sector which has been longest under examination, which is repeated exactly in the other eye. At a first sitting only the principal meridians should be measured, and the patient should be allowed several hours' rest before proceeding to measure the whole of the meridians of a single eye, leaving the examination of the other eye till the next day whenever possible. The examination must always be stopped if the patient shows the least sign of fatigue. If it can be managed, a second measurement of the field of vision should be made a few days later so as to make sure of the permanence of its limits. If the visual defects are very small and near the fixation point, an index only one-twelfth of an inch square should be used, and Pigeon's stereoscope, by which a more exact measurement of the limits of the scotoma can be made, should be substituted for the perimeter.

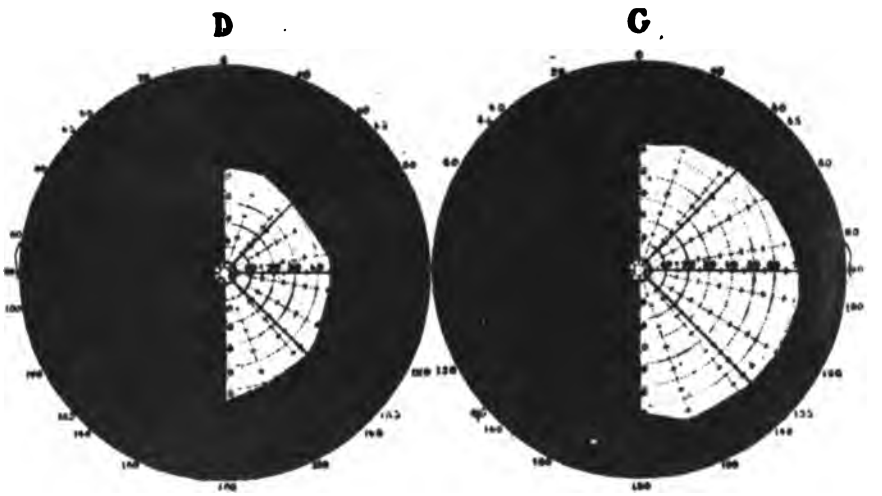
The Types of Modification of the Field of Vision

Homonymous lateral hemiopia.—Lateral hemiopia through a direct wound of the occipital lobe and isolated destruction of the field of vision on one side only appears to be somewhat rare. If the injury is severe the visual lesion is bilateral, and there is either cortical blindness or an inferior hemiopia. If the injury is moderate, there is not complete lateral hemiopia, but a uni- or bilateral hemiopic defect. Complete typical lateral hemiopia is nearly always due to a lesion of the occipital region more or less external relatively to the median line, penetrating very deeply into the white matter of the occipital lobe and injuring the optic radiations. In many cases

the missile enters the skull a long distance away, and reaches the occipital lobe after having severed the radiations, thus causing hemiopia. Homonymous lateral hemiopia from war-wounds does not, as a rule, display any special clinical symptoms. The vertical limit of the blind area passes through the point of fixation itself, or does not touch the macular field on the side of the hemiopia within a radius of 5 to 10 degrees around the fixation point. The hypothesis upon which these variations are accounted for will be dealt with when we speak of macular and paramacular scotomata. In any event, it appears to us that the fact that the limit of the field of vision passes through the fixation point, or does not touch the macular field, does not seem to deserve the importance attributed to it by some writers; a hemiopia passing through the point of fixation would indicate a lesion of the optic tract (see fig. 19).

It is not necessary to enlarge on the symptoms associated with hemiopia in cases of indirect wounding of the occipital lobe by a missile; it is only necessary to mention the possibility of alexia when there is right homonymous lateral hemiopia. In this case the patient loses the capacity of reading, which must not be confused with the difficulty of reading caused by the diminution of the visual acuity. This pure, or almost pure, alexia occurs when the lesion of the occipital lobe extends very deeply to the convolutions on its inferior aspect (the lingual and fusiform lobules) adjacent to the deep portion of the white matter of Wernicke's zone, or the zone of language. There is then a lesion of the visual area with slight damage to this zone of language or of the fibres which proceed from it, that causes alexia (Pierre Marie). If the lesion impinges a little further on the zone of language, the alexia will be associated with a series of symptoms of sensory aphasia of varying intensity.

Figs. 21 to 24 show the field of vision in two cases of homonymous lateral hemiopia selected from those we have observed. Fig. 21 is a case of a direct wound



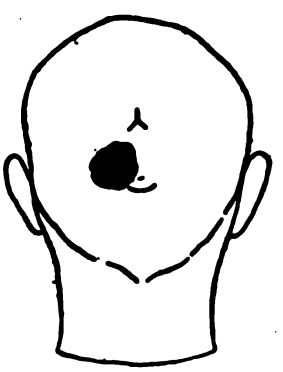


FIG. 21.—The wound in the skull.

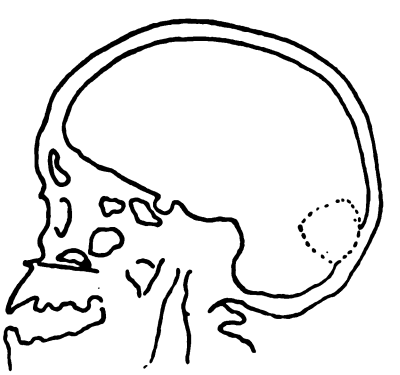


FIG. 22.—Radiograph in profile showing loss of bone.

Right homonymous lateral hemiopia.

of the occipital region, with extensive destruction of the occipital lobe; there was almost pure alexia associated with hemiopia. In the other case there was a deeply penetrating wound of the external

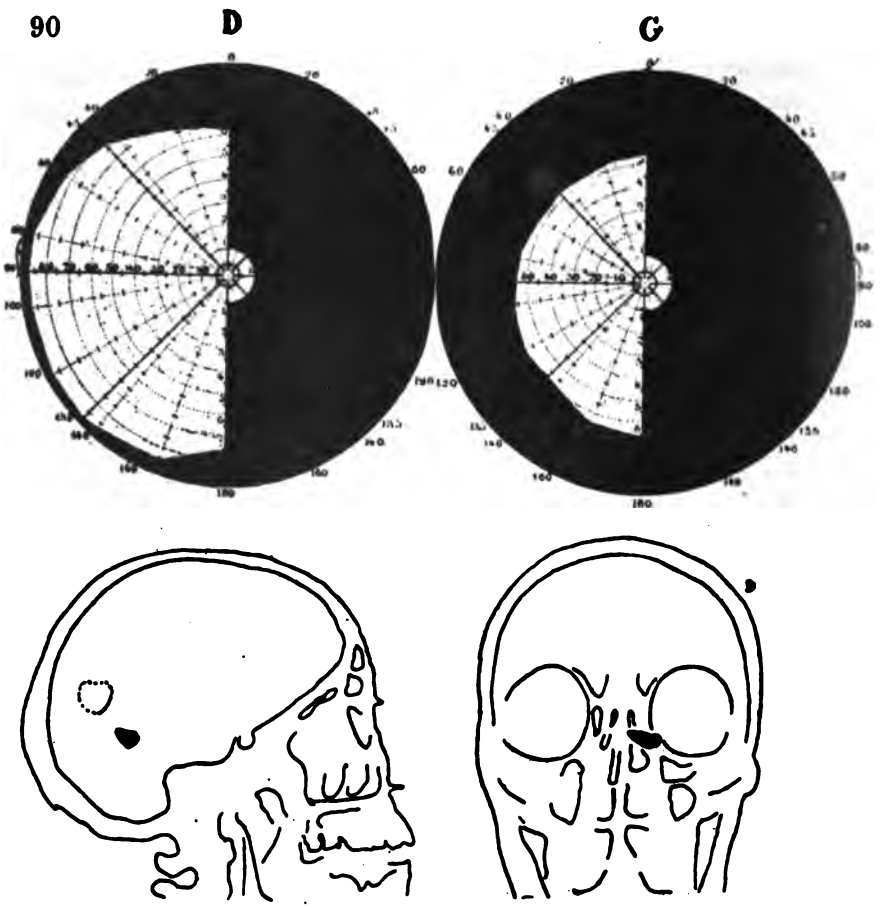


FIG. 23.—Radiographs in profile and full face showing intra-cerebral missile.

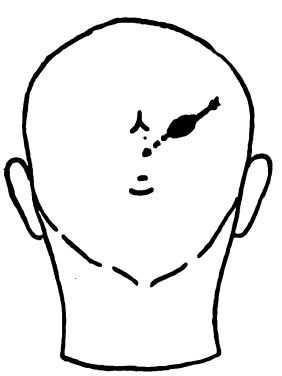


FIG. 24.—The wound in the skull showing the orifice of entry.
Left homonymous lateral hemiopia.

aspect of the occipital lobe, with a missile which had severed the optic radiations lodged deep in the lobe near the median line.

Cortical blindness is caused by extensive destruction of both occipital lobes, or, at the very least, of the visual centre; it is very seldom seen, as the injury is generally so grave as to prove fatal. On the other hand, it is quite common to see cortical blindness precede the other forms of visual disorder for a period, often very brief; but there are cases in which the blindness may continue for months, and in these there is reason to suspect a neuritic complication due to anterior cerebral hypertension or infection. The fundus and the condition of the pupil must then be examined in order to eliminate the possibility of a neuritic complication, and to establish the diagnosis of cortical blindness. In the history of cases of occipital wounds there is nearly always found the anamnesis of a cortical blindness, which lasted a few hours or days and passed away, leaving in its place a more or less extensive hemiopic defect. This transitory cortical blindness is caused by inhibition of the visual centre by shock and the compression due to the œdema consequent on the lesion; it is not due to permanent and total lesion of the area. Transitory blindness of this kind does not generally amount to complete amaurosis; some perception of light is generally retained. Vision often returns in the superior portion of the field, and is accompanied by brilliant phosphenes which indicate irritation of the visual area.

Inferior hemiopia.—In the pre-war period the syndrome of inferior horizontal hemiopia was exceptional in neuro-pathology, and was often attributed to lesion of the chiasma. Professor Lapersonne was the first to contend that this type of hemiopia was due to lesion of the occipital lobe. As might be

expected from the arrangement of the calcarine fissure, it is very frequently caused in this way. On the other hand, for the reasons stated above, superior horizontal hemiopia is extremely rare, as any wound which could injure the inferior portion of the visual centre alone must likewise cause lesion of the cerebellum and of the venous sinuses on both sides, and would certainly cause death. This variety of hemiopia is due sometimes to missiles entering transversely above the external occipital protuberance, and sometimes to direct lesions of the occipital bone in the median line. More rarely it is caused by a wound of the parietal region on one side, the missile travelling obliquely into the occipital lobe of the opposite side.

Inferior horizontal hemiopia is nearly always preceded by a period of more or less complete blindness (cortical blindness), which lasts for a few days or weeks; then the superior portion of the field of vision becomes brighter, vision again becomes normal therein, and examination with the perimeter will show an inferior horizontal hemiopia several months after the wound. It is important to observe that this examination will show that the anopic region does not reach right up to the horizontal meridian, as it does to the vertical meridian in the case of homonymous lateral hemiopia. Sometimes there is a more or less extensive field of vision below the horizontal meridian, and sometimes the defect encroaches on the superior portion, but the defect is always nearly perfectly symmetrical in both homonymous quadrants of the two fields of vision. The name "horizontal hemiopia," therefore, appears to be hardly justified; it is rather a case of bilateral scotoma in sector, or bilateral quadrantic hemiopia. Nor is it uncommon to find this hemiopia diminish to an inferior hemiopic scotoma by the return of vision to the peripheral portion of the field if the wound is not more than a few months old.

In every case which has come under the writer's personal observation the data furnished by the site

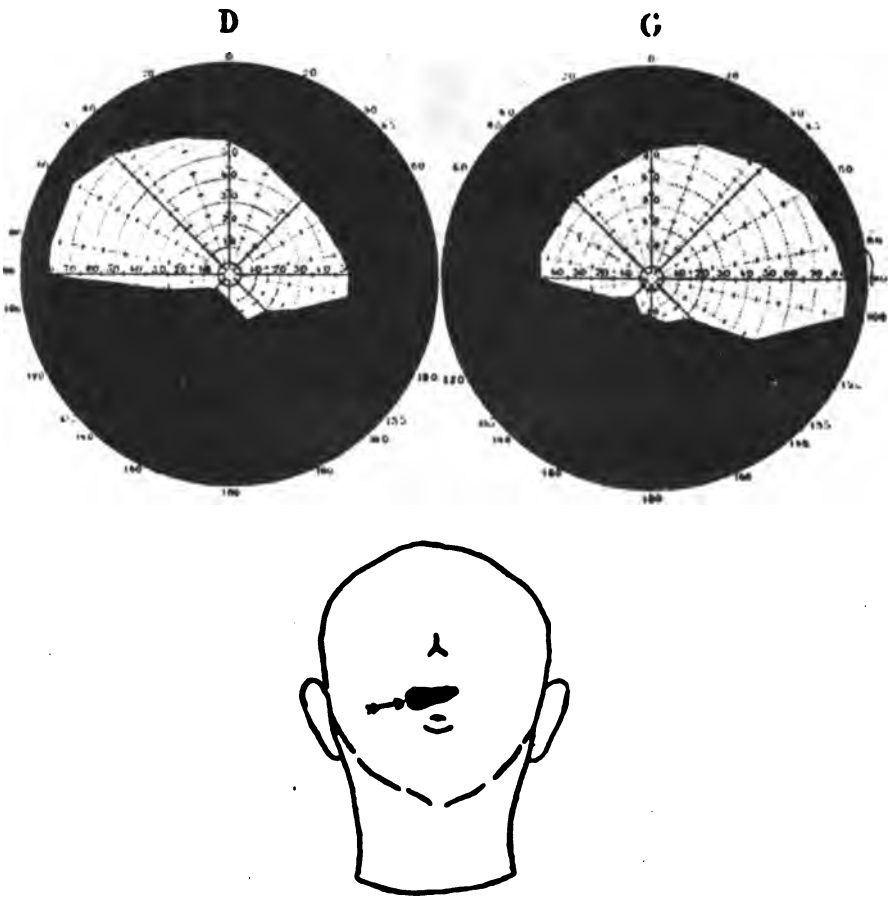


FIG. 25.—The wound in the skull.
Inferior hemiopia.

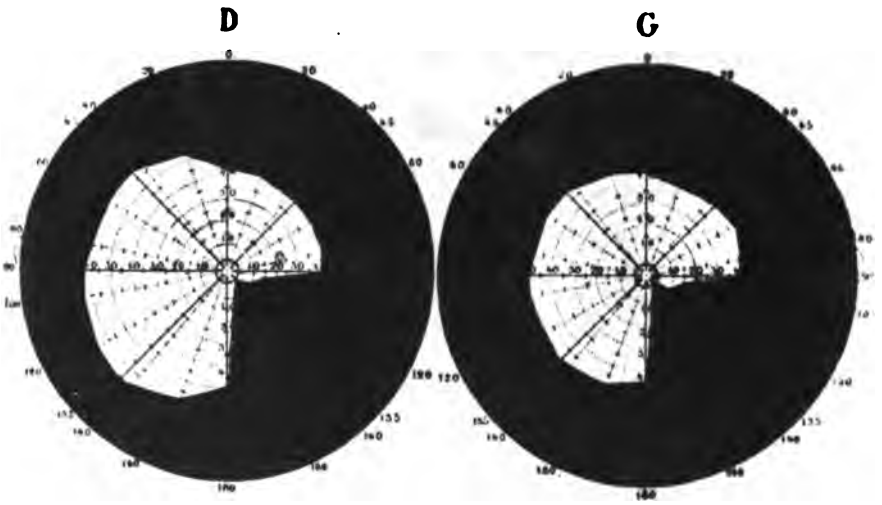
of the wound, by the direction of the missile, and by radiographs have demonstrated that it was always the superior portion of the visual area that had been injured. Fig. 25 shows a typical example of this form of hemiopia.

Quadrantic hemiopia. — In this form of hemiopi it is almost always one of the inferior quadrant which is affected, and the defect occurs in the homony mous quadrant of each field of vision, but the superi form is not so rare as the other forms of hemiopi

FIG. 26.—Type of occipital wound with quadrantic hemiopia.

Inferior quadrantic hemiopia is caused by a dire wound of the external table of the occipital bo above the protuberance, beyond which the depressi of the bone does not pass. Indirect wounds appe more frequently to give rise to superior quadran hemiopia. In all cases of this variety observed the writer the site of the wound had been behind t ear, and quite close to the base of the mastoid proces the missile, travelling very obliquely backwards, h

followed the inferior aspect of the occipital lobe, and has been arrested near the median line. This variety



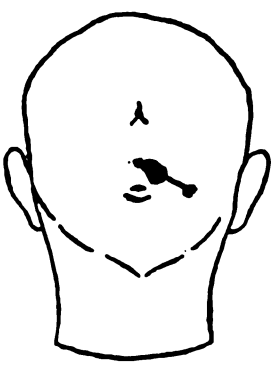


FIG. 27.—The wound of the skull.

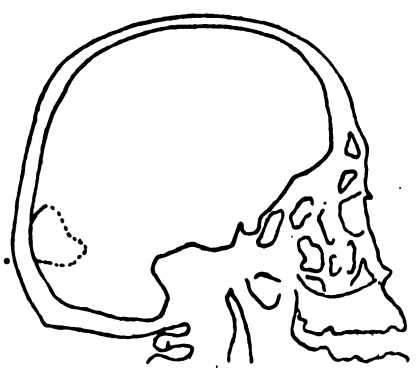


FIG. 28.—Radiograph of the skull in profile showing loss of bone.

Hemiopia in the left inferior quadrant.

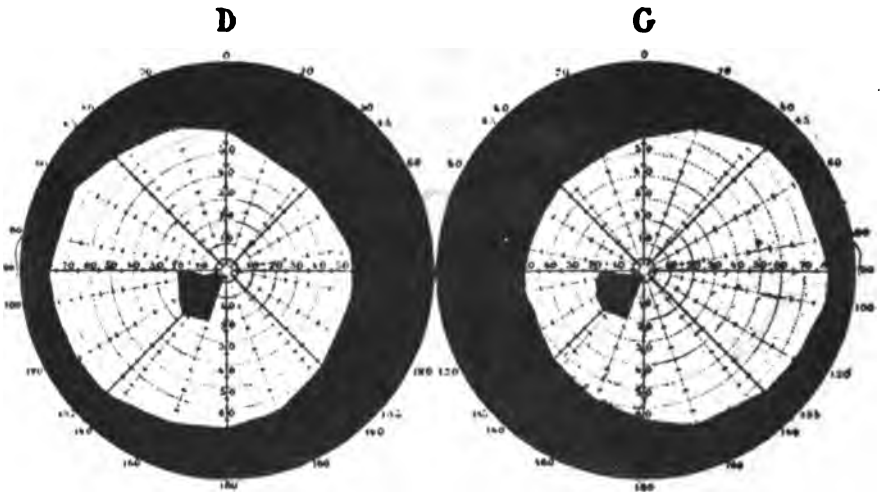
of lesion of the visual centre must be methodically looked for in every patient who has a wound in this position, because, in such cases, the disorder of vision is nearly always unperceived. But inferior quadrantic

hemiopia is the most common variety, the blind area in the field often reaching the fixation point, and it is sometimes complicated by hemiachromatopia in the homonymous superior quadrant. In the cases observed by the writer the limits of the defect of vision have continued unchanged after several months. The site of the wound, its direction, and the radiographic localisation of the missile (if it is still present) all show that the injury is confined to one portion only, either superior or inferior according to the case. Sometimes, instead of the wound being limited entirely to one lip of the calcarine fissure it will have slightly touched the other also, which will be shown in the field of vision by a small scotoma being added to the hemiopia in the quadrant affected.

Fig. 27 illustrates a typical case of quadrantic hemiopia by direct wound.

Hemiopic scotoma.—This is the most common form of disorder of the vision caused by wounds in the occipital region. The scotoma is always negative, that is, it does not appear as a black patch in the field of vision, and is consequently nearly always unperceived by the patient. It is usually absolute, the loss of vision within its area being complete. Sometimes, but much more rarely, the scotoma is only relative, the visibility of the white index only diminishing instead of disappearing altogether during part of its passage. These scotomata appear in all sorts of shapes, though they may extend over only a few degrees. Their number, as well as their position relatively to the fixation point, is very variable. They can be divided into three classes: (*a*) macular and paramacular scotomata, (*b*) pure macular scotomata, and (*c*) peripheral scotomata. In most cases the site of the wound is in the immediate neighbourhood of the external occipital protuberance, either in the median line or slightly on one side of it. According

to the descriptions of operations or the information obtained by radiography, there is often damage to



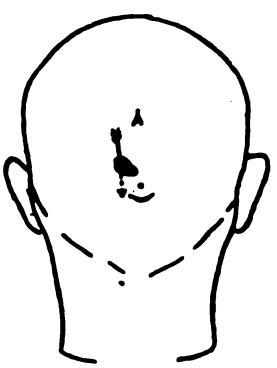


FIG. 29.—The wound of the skull.

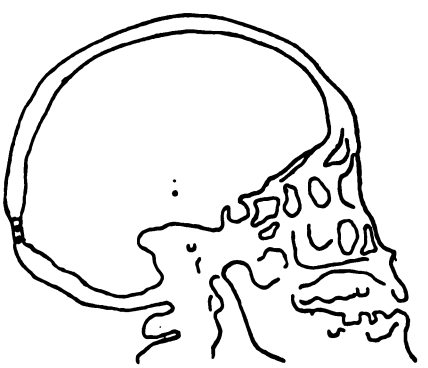
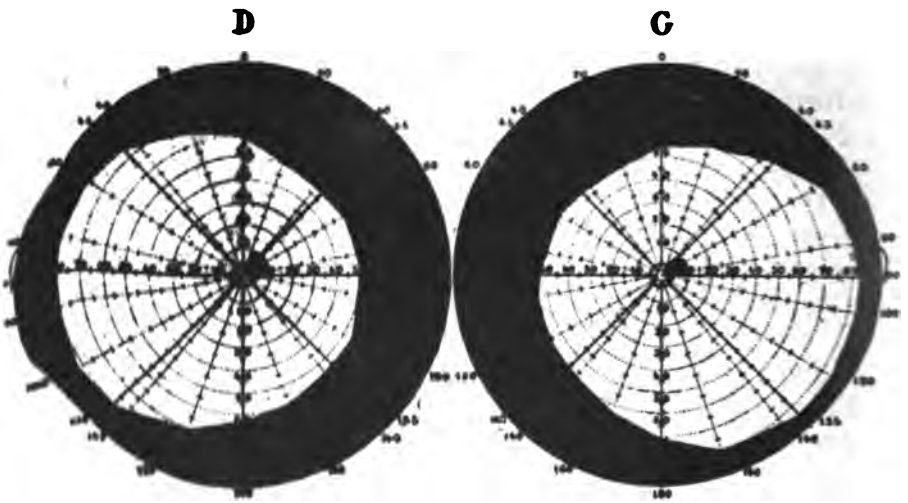


FIG. 30.—Radiograph of the skull in profile showing fracture with depression of the occipital bone.

Right inferior hemiopic scotoma.

the brain by the missile or by splinters of the internal table of the skull. Most frequently there has been total blindness at the moment of wounding, which has

persisted for a few hours or days and then disappeared, the restoration of vision appearing to be perfect. If



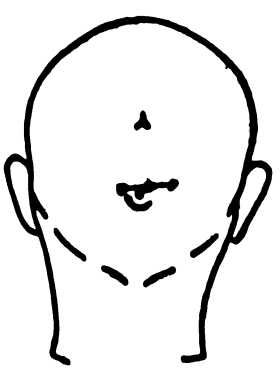


Fig. 31. The wound of the skull.

Fig. 32.—Radiograph of the skull in profile showing fracture of the internal table and an intra-cerebral splinter.

Left superior macular and paramacular hemiopic scotoma.

the patient is examined several months after the injury, he will be unconscious of any defect in his vision; it is only minutely methodical examination

of the field of vision with the perimeter that will bring it to light. These scotomata are always homonymous, or situated in the same portions of the field of vision on each side; they are almost mathematically identical in the two fields, and they are constant in shape even when they are very small. Repeated examinations of a patient at intervals of several months have yielded identical results.

If the data derived from the site of the wound, from observations made when the patient first came under surgical treatment, and from radiographs are compared with the position occupied by the scotoma in the field of vision, interesting information respecting the localisation of the visual area can be obtained. Thus purely macular scotomata situated within 10 degrees of the centre of the field of vision are always caused by a small wound of the occiput situated immediately above and slightly to the side of the external occipital protuberance, which therefore almost exclusively affects the extreme point of the occipital lobe. Peripheral scotomata, on the other hand, are caused by much more anterior lesions of the visual area. It must be repeated that it is especially necessary in cases of scotoma to measure the visual acuity and carefully to examine the fundus in order to eliminate any lesion of the macula.

Hemiachromatopia.—This type of disorder of the field of vision appears rarely to occur alone, but is pretty frequently associated with quadrantic hemiopia or hemiopic scotoma. This disorder is generally transitory, being the residuum of a hemiopia which has disappeared, and it also disappears in its turn. It does not appear to be caused by lesion of a special visual colour centre, but rather by slight injury of the general visual centre or of the optic radiations, but in every case of wound of the occipital region the perimetric examination for colours must be carried

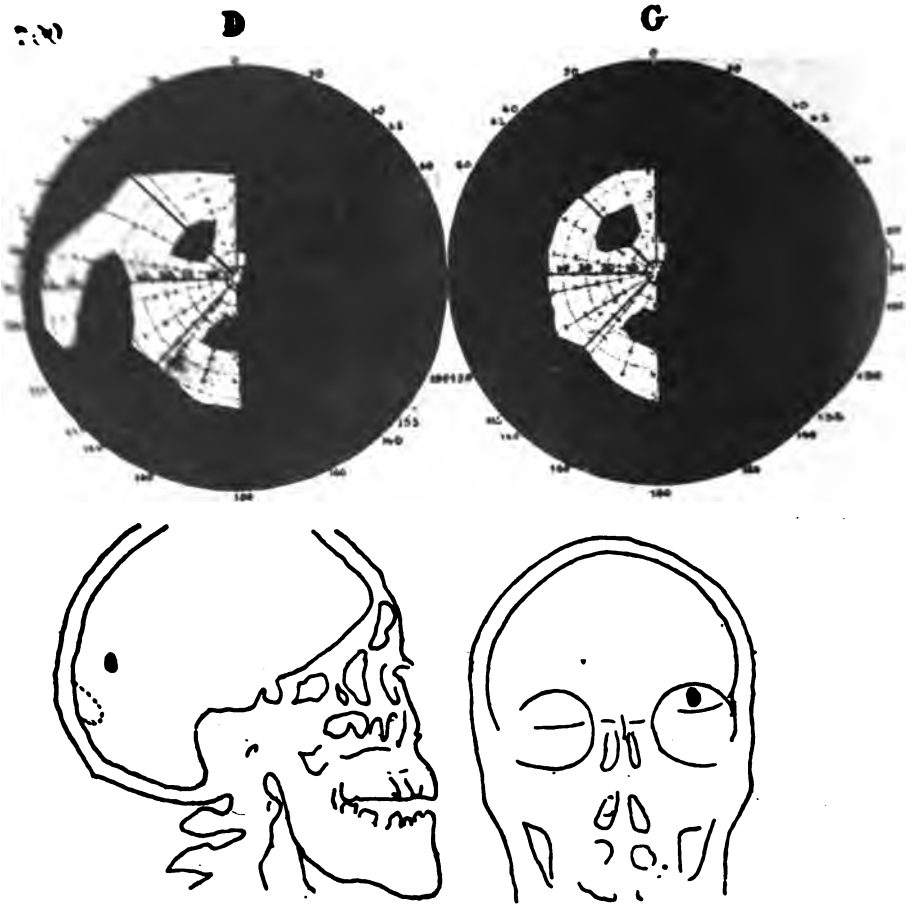


FIG. 33.—Radiograph of the skull in profile and full face showing an intra-cerebral missile on the side opposite to the orifice.

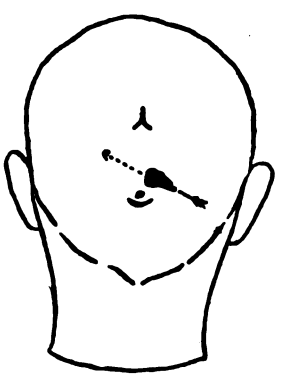


FIG. 34.—The wound of the skull.
Complex form of defect of the visual field.

out, even if the field of vision appears to be normal for white light.

Complex defects of the field of vision.—Besides the classical types of modification of the field of vision which have been described, extremely complex defects of a hemiopic type may be caused by wounds of the occipital lobe. It would take too long to describe these, but their existence will be fully understood if the idea of a projection of the retina on the cortex of the calcarine fissure is borne in mind. If a projectile traverses the occipital lobes from side to side, or if irregular splinters penetrate more or less deeply into the visual centre, there will be found an extremely irregular patch of anopia, which will always have one absolutely constant characteristic—symmetry of the defect in each moiety of the field of vision. In figs. 83 and 84 is shown a case where the missile has entered to the right of the median line near the protuberance and has been arrested deep in the left occipital lobe; there is a lateral hemiopia on the left, and three hemiopic scotomata on the right.

Course of Disorders of Vision

The patients do not usually present marked symptoms of disordered vision except at the time of being wounded, when there is immediate blindness (often of brief duration) followed by rapid return of vision; then the visual defect becomes fixed, the patients generally remaining unconscious of it. If the defect is still observed several months after the wound, it has become permanent. Symptoms of irritation of the visual area are frequently added to these symptoms of inhibition or destruction. At the very instant of being wounded, and before the loss of sight, some patients see an appearance as of a huge flame in front of their eyes; later on, the return of the sight

is accompanied by luminous phosphenes (sparkling coruscations of all colours) over all that portion of the field of vision in which the sight is returning. In some cases there are even visual hallucinations, such as persistence of the image of an object which has disappeared, or the appearance of animals of strange shapes in the blind part of the field. At a very late stage the syndrome of characteristic hemiopic migraine, with a scintillating scotoma and lateral hemiopia lasting several hours, has been observed in some patients affected by macular scotomata, the result of a lesion of the apex of the occipital lobe, and even true epileptic fits commencing with a scintillating scotoma.

Everything that we have seen since our first study of occipital wounds goes to confirm the views we have put forward above.

Up to the present time we have seen close upon one hundred and fifty cases of wound of the occipital region with hemiopic visual affections which have all been examined several times.

We wish to lay stress upon the permanence of the defect in the field of vision when the patient is examined more than six months after the injury if no complication has arisen meanwhile. These facts come out particularly when we are dealing with cases presenting a small macular or paramacular scotoma the dimensions of which can be accurately defined.

Associated Symptoms

It is not necessary to particularise the subjective symptoms, such as severe headache or vertigo, of which many patients complain, as there is nothing special about them in connection with wounds of the occipital region. It is, however, necessary to see whether there is any *disturbance of the sense of locality*,

such as have frequently been observed by the writer, the patient not being able to recognise his own bed, or being unable to find his way when walking in the street, or to recognise streets through which he has frequently passed. In practice the test can be made by asking the patient to give the route between two places that he knows well, and, if necessary, he may be made to trace out the route on a map.

Alexia has already been described in connection with homonymous right lateral hemiopia.

Complications.—There are no complications peculiar to wounds of the occipital lobe. There may sometimes be an abscess, or encephalitis may occur, and there may be crises of true epilepsy; sometimes associated with the headache of hemiopia. But unilateral or bilateral *affections of the labyrinth* are especially common, with impairment of hearing and labyrinthine vertigo, and are caused by lesion at a distance of the labyrinth, by "contre-coup," or by a fracture extending to the petrous bone. The labyrinthine syndrome is dealt with in connection with wounds of the cerebellum.

Radiography.—In the wounds of the occipital lobe radiography will give information of the greatest importance. Besides often showing the presence of an unsuspected missile in the brain, it may, theoretically, take the place, to some extent, of an anatomical investigation, and give fairly accurate indications as to which portion of the lobe has been affected. The following is the method we have adopted for obtaining a control by using a formalin brain hardened *in situ* and then removed. The calcarine fissure in each hemisphere has a lead wire laid along its whole length; the optic radiations are marked out with small leaden pellets from the cortex to the chiasma. The brain is then replaced in its cranium and radiographed antero-posteriorly and laterally in exactly

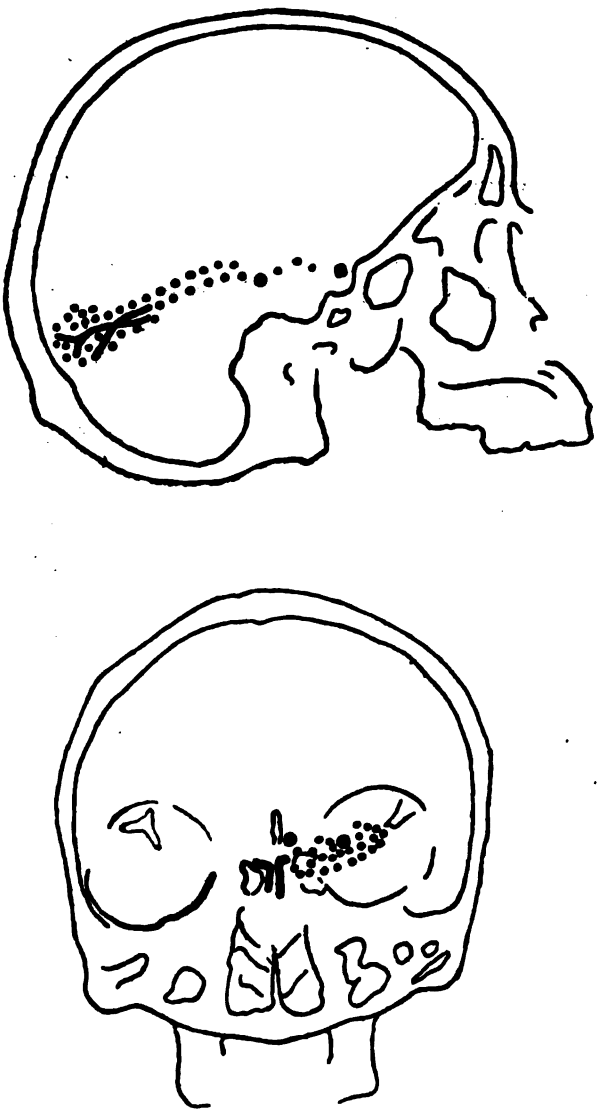


FIG. 35.– Radiograph of a brain replaced in the skull, in which the calcarine fissures and the central optic tracts on the right side have been mapped out with threads and fine shot (full face and profile). The two larger-sized shot correspond to the corpus geniculatum externum and the centre of the chiasma.

the same position as the skulls of the patients by means of M. Infroit's special apparatus. By placing an accurate tracing of this radiograph over a tracing of the radiograph of the patient's skull the position of the missile and its path in relation to the optic radiations and the calcarine cortex can be very satisfactorily determined, and in every case in which we employed it positive results were obtained. This method is by no means equal in value to a direct anatomical examination, but the conclusions derived from it, together with our own clinical observations, confirm the results obtained by Henschen by combined anatomical and clinical methods, and help to establish the view as to the projection of the retina on the calcarine cortex.

Surgical intervention.—The question as to whether there should be surgical intervention in cases of wounds of the occipital lobe requires the most careful consideration. When there are signs of suppuration, caused by splinters at the orifice itself or when symptoms of a deep-seated abscess can be seen, immediate operation is indicated; but it is much less certain that an operation is desirable if there is a foreign body seated deeply in the occipital lobe which does not apparently give rise to any symptoms of inflammatory complication. If the missile has been *in situ* for several months an operation will not effect any improvement in the defect of vision, which has by this time become permanent, but may increase it by dividing or destroying some other portion of the radiations or of the visual cortex, and it is therefore better not to operate.

CHAPTER IX

WOUNDS OF THE CEREBELLUM

Anatomy

THE cerebellum is the portion of the brain which occupies the inferior occipital fossæ.

Situation and connections.—It is placed below the occipital lobes, from which it is divided by the tentorium cerebelli. It rests on the occipital bone, which is covered externally by the muscles of the neck, and in front is supported laterally by the posterior surfaces of the two petrous bones; in the median line it is separated from the basilar process by the medulla and the pons. The centre of its greater circumference or posterior border corresponds to the external occipital protuberance.

The knowledge of this very low position of the cerebellum is very important, and must be carefully borne in mind; it is a common mistake to suppose that the cerebellum is much higher up and more accessible than it really is. This is dealt with again in connection with the site of wounds of the cerebellum. A wound of the skull does not certainly and directly affect the cerebellum unless it is situated below a line drawn from the external auditory meatus to the external occipital protuberance.

The cerebellum has a superior aspect entirely covered by the cerebrum. In the centre of this

superior aspect, and running from before backwards, is the superior vermiform process of a herring-bone pattern wedged in between the two lateral lobes, the sloping sides formed by the hemispheres of the cerebellum giving rise to an incline like the ridge of a roof. This is important to remember, as the vermiform process may thus be the only part to be affected by a wound of the occipital region.

The inferior aspect is convex, and deeply furrowed in the middle by an antero-posterior sulcus which separates the two hemispheres of the cerebellum, and at the bottom of which is the inferior vermiform process. The circumference of the cerebellum corresponds in front to the superior border of the two petrous bones, is grooved along its middle to receive the medulla and pons, and helps to form the fourth ventricle. The whole of the posterior border of the circumference corresponds to the transverse groove on the occipital bone occupied by the lateral sinus and, in the median line, the torcular Herophili.

Cerebellar tracts.—The cerebellum is united to the cerebrum and the medulla by three pairs of peduncles; the inferior cerebellar peduncles connect the cerebellum with the medulla and the spinal cord by means of the direct cerebellar tract, Gowers' tract, and fibres emerging from the posterior cornua; these are the afferent fibres to the cerebellum, some direct and others crossed. There are also efferent fibres, the descending cerebellar tract. The middle cerebellar peduncle unites the cerebellum to the grey nuclei of the pons. The superior cerebellar peduncles are made up of efferent fibres, which go from the cerebellum to the nuclei of the tegmentum (or red nucleus), and to the optic thalamus on the opposite side.

Morphology.—The cerebellum was formerly divided into three lobes; a median lobe made up of the superior and inferior vermiform processes, and two

lateral lobes or cerebellar hemispheres. The lobes and vermis were cut up into lobules by deep transverse sulci. The lobules and sulci were arranged *en échelon* on each hemisphere thus: On the superior aspect from front to back, the quadrilateral lobe, the great superior fissure, the lobus cacuminis, and the great horizontal fissure. On the inferior aspect from front to rear, the amygdala, the biventral lobe, the lobulus gracilis, the pyramid, and the inferior semilunar lobe bounded by the great horizontal fissure. The vermiform process was also divided into two parts, the superior and the inferior, and subdivided into differently named lobules, concerning which it is not necessary to enter into detail.

Bolk, as the result of very minute and careful researches in comparative anatomy, proposed an entirely different division. He proposed to abolish the old nomenclature, and to recognise only an anterior and a posterior lobe separated by a primary sulcus. It is the posterior lobe only which undergoes very great modifications of morphology throughout the animal series, and reasoning from these modifications, Bolk drew the following physiological deductions which have been largely confirmed by experiment and clinical observation: That there are in the cortex of the cerebellum (as well as in the cortex of the hemispheres) centres of localised functions which are centres of representation of the muscular groups, some median, and unequal, appropriated to synergic movements, and others unilateral, appropriated to unilateral movements. These results may not appear to have any direct bearing on wounds of the cerebellum, but it may be that in the future this theory of localisation may enable cerebellar lesions to be exactly located and facilitate surgical intervention.

Physiology

Every author who has dealt with the functions of the cerebellum has endeavoured to define precisely its general function. This has resulted in very contradictory theories, because they looked upon the cerebellum as a whole, without making any distinction between the individual functions of the cerebellar cortex, the white fibres, and the grey nuclei.

Experiments on animals.—Reasoning from results obtained by extirpating the cerebellum in animals, various authors in succession have considered the cerebellum to be the central organ for the co-ordination and regulation of movements, the centre for equilibrium, and the centre for static perception. Luciani grouped the symptoms consequent on removal of the cerebellum under three heads: asthenia, or impairment of the normal tonicity of the muscles in action; atonia, or relaxation of the muscles in repose; and astasia, or irregularity in bringing into play the elementary impulses necessary for a contraction, thus causing tremor and staggering. Munk, reasoning also from numerous experiments on animals, made the cerebellum the centre for unconscious, combined, and co-ordinated movements of the trunk and limbs. It is evident that there is a conflict of opinions, and besides, as experiments on different animals fail to give identical results, it is obvious that the results of such experiments cannot be held to apply strictly to man. As a matter of fact, comparative anatomy proves that the anatomical system of the cerebellum is highly complex (Bolk). The cerebellar function is carried out by the activity of the cortex and the grey nuclei, concerning which our knowledge is very scanty. A more reliable theory of the physiology of the cortex of the cerebellum can only be obtained

by methodical study of localisation in the cerebellar cortex and of its relations with other portions of the central nervous system. Our present knowledge of this subject is still trifling. However, we are beginning to be able to distinguish between an injury to the cerebellar hemispheres and an injury to the vermis, and to make out some of the localisations in the cortex itself. Researches instigated by the very careful work of Bolk show that in the animal (monkey and dog) the extirpation of very circumscribed and strictly defined portions of the cortex bring on symptoms of defect in certain well-defined regions of the body, but Sherrington's experimental lesions of the central grey nuclei gave much less reliable results. The uncertainty of these experiments is greatly enhanced by the fact that rapid repair occurs in the cerebellar cortex after local destruction, especially in the monkey. The experiments of A. Thomas and Rothmann, however, have shown that there are distinct centres in the cortex of the hemispheres for the movements of abduction, adduction, elevation and depression of the homo-lateral limbs, which are not so much motor-centres, properly so-called, as " centres for the direction of movements " ; analogous centres for the muscular systems of the head and neck in the cortex of the vermiform process ; and in the cerebellar cortex, separate centres for the " interaction " of the agonistic and antagonistic muscles of particular joints. These are facts of the greatest importance, because they coincide most remarkably with the results of Barany's clinical researches on man. It would be of little use to recount in detail the complicated history of the almost useless experiments on animals carried out in former days, but it is of great interest to record these recent data, which seem to open out a new path for the physiology and pathology of the cerebellum.

Semeiology of the Cerebellum in Man

Technique of Testing the Cerebellar Functions

Instead of repeating the details of the symptomatology of cerebellar lesions in man it will be more useful to describe the procedure to be observed in the examination of the cerebellar functions, which is calculated to facilitate the search for symptoms. It is not necessary to repeat here the method of testing the muscular energy, the reflexes, the sensibility, etc., which should be carried out on the general lines laid down at the beginning of this book.

A. The Classical Tests

Equilibrium in Repose.—*Subjective disorders of equilibrium. Interrogatory.*—Has the patient vertigo, and if so, in what position? When erect, or when lying on one side, or when lying on his back? Do sudden movements of the head bring on the vertigo? In what direction does he feel himself inclining? Is it always in the same direction? Do objects which he looks at appear to revolve, and in what direction? Does shutting the eyes reduce the vertigo?

The information derived from this interrogatory is valuable, although the subjective sensation of vertigo may arise from many other than cerebellar lesions; nevertheless a permanent sensation of being always drawn in one direction, which is not diminished by closing the eyes, is in favour of its being a cerebellar vertigo. The most difficult question to decide is that of vertigo of labyrinthine origin, which will be dealt with later.

Objective characteristics of equilibrium in repose. Examination for equilibrium.—Is the patient able to

stand up, with his feet together, or with his heels together, or with his legs apart at any distance he pleases? Is the patient's position perfectly stable in all, or any, of these positions? If there is an inclination to fall over, in what direction? Is it always in the same direction? Let the patient stand on tiptoe or on one leg. Is the equilibrium affected by the position of the head, when turned backwards, or to the right or left? Let the patient make these movements sharply, and note whether this upsets his equilibrium.[1] Make the patient repeat these movements with his eyes shut.

To test the power of resistance to impulsion. While the patient is standing steadily, push him on the back, or chest, or on the side as if you were trying to upset him, telling him to resist the pressure; suddenly stop the pressure and note whether there is a marked disturbance of equilibrium, and if so, in what direction?[2]

KINETIC EQUILIBRIUM. TESTING THE GAIT. — The patient is told to stand erect with his feet together and to start walking. As soon as he starts note whether there is a tendency in the trunk to remain behind, causing the patient to fall in that direction (*cf.* cerebellar asynergia). While he is walking note whether the patient deviates from side to side of the line which he has been told to follow; if he staggers; if there is a tendency to deviate always to the same side. Note whether the patient walks with his legs wide apart; whether in walking he raises one or

[1] Some of Stein's tests with an inclined plane may be employed. The patient is made to stand on an inclined plane, the inclination of which is varied to different angles, and the test repeated with the patient in different positions; with his face, back, and each side turned towards the upward inclination of the plane, and the conditions under which he falls are noted.

[2] If there is a tendency to fall over, the manner of falling must be noted. As a rule, cerebellar subjects fall in a lump without making any effort to prevent it or to preserve their equilibrium (Babinski).

both legs too high, or too sharply; if his feet strike the ground hard as he steps. Tell the patient to make a half-turn or to stop suddenly at any point in his walk, and note the loss of equilibrium so produced.

It is of great importance carefully and minutely to study the walk of a cerebellar subject, as it often brings out very trifling disorders which the most careful analytical examination would not show. All these tests are directed to the static and kinetic equilibrium of a cerebellar patient, and include nearly the whole of the observations which could be made previous to Babinski's work, which is the real foundation of the clinical semeiology of cerebellar cases. The series of indications which will now be described must always be methodically looked for in cases where lesion of the cerebellum is suspected, and they will also explain most of the disorders of walking and equilibrium mentioned above.

B. Examination for Babinski's Cerebellar Syndrome

1. EXAGGERATED MOVEMENTS (HYPERMETRIA).—When a patient has a lesion of the cerebellum it will be observed that "voluntary movements, or at least some of them, and in certain conditions, will be executed in an exaggerated manner" (Babinski). This may be seen in his spontaneous actions, such as walking. In the first group of the motions of walking the flexion of the thigh on the pelvis is exaggerated, and the foot is raised much too high; in the second group the thigh is extended too sharply, and the foot comes down heavily to the ground. But actions to order will show this more clearly.

(A) *The upper limb.*—(*a*) The patient is told to put the end of his index finger on his nose, then to extend his arm laterally as far as possible, and repeat

the action four or five times; he is then told to perform the test at varying speeds, first with the right arm and then with the left, and then with the two arms alternately. A healthy patient will hit the mark every time, but a cerebellar subject will overshoot it and touch his cheek or his eye.

(*b*) The patient is seated and told to place the palm of his hand on his knee on the same side, then to turn the hand over and replace it on the knee with the palm upwards on exactly the same spot, and to repeat these actions rapidly. A healthy subject will carry out these movements easily and correctly, but with a cerebellar patient the hand will slip down between the knees.

(*c*) The observer draws a vertical line on a piece of paper, and tells the patient to draw another line from any point to the left and to make it touch the vertical line exactly; a cerebellar subject will nearly always go beyond the vertical line.

(B) *The lower limb.*—(*a*) While the patient is lying on his back he is told to put the heel of one foot on the knee on the other side, to keep it there a moment, then to extend the leg again, and to repeat the movement four or five times. A cerebellar patient will raise his heel too high, too far, or too much outwards, and will drop it more or less abruptly on his knee.

(*b*) The patient while lying on his back is told to bring his heel into contact with his buttock, then to extend the leg, and to repeat the movement four or five times. A cerebellar subject will strike the buttock abruptly with his heel and then let it fall suddenly on the bed.

A cerebellar subject can execute these movements fairly correctly if they are carried out slowly, so the tests must be made in quick time. It will frequently be observed that though the first movements are

much exaggerated, the later ones are less so. The disorder only becomes evident towards the close of the movement; the course is correctly followed by the limb till near the end. when the characteristic disorder, dysmetria, will become evident. The fact that closing the eyes does not increase the disorder observed in these tests enables the observer clearly to distinguish hypermetria from ataxia. These dysmetric disorders have an important bearing on the location of the injury, as when they are found on one side only the lesion of the cerebellum will be on the same side, the cerebellar tracts being direct and not crossed.

2. ADIADOCOCINESIA is "the destruction or the diminution of the power of executing rapidly successive voluntary movements." If a healthy subject is told to place his hand rapidly and alternately in pronation and supination, the movement will be performed more or less rapidly according to the individual, and also according to whether the right or the left hand is used. With a cerebellar subject it will be observed that while either pronation or supination can be performed rapidly and correctly, the alternation of the movements is much slower than in a healthy subject. In carrying out this test it is essential first to make sure that the subject can carry out rapidly the movements of pronation or supination separately, and that there is no associated paresis. Adiadococinesia may be either bilateral or unilateral, and in the latter case the lesion of the cerebellum will be on the same side.

3. CEREBELLAR CATALEPSY.—Babinski describes under this name a phenomenon characterised by prolonged voluntary immobilisation of the muscles in certain positions of static equilibrium. The patient is laid on his back and told to raise his legs in the air with his knees slightly bent and his feet apart, and to

maintain this position as long as possible. A cerebellar subject will execute the movement with more or less large oscillations, then the lower limbs become fixed, "and this fixity is remarkable in its completeness, being greater than that which a normal subject is able to produce." It is maintained for several minutes, and does not appear to be accompanied by any sensation of fatigue. It is rare to see the phenomenon in such perfection, and in any event it is important to note that some cerebellar patients who present titubation and asynergia are able to maintain this attitude as well as a normal subject.

4. Cerebellar Asynergia.—According to Babinski, asynergia is characterised by loss of the faculty of association of movements through want of synchronisation; the following examples will show its characteristics and nature more clearly than a mere definition. It can be very plainly observed in the act of walking, for when the patient starts to walk, he bends his thigh and puts his foot forward in a way which is often exaggerated, but the upper part of his body does not follow the movement of translation. His trunk, instead of being inclined slightly forward remains erect or is even inclined slightly backwards, and when the patient tries to take another step the trunk does not follow, and he falls backwards if not supported.

Babinski has provided a series of clinical tests which make the presence of asynergia perfectly clear.

(*a*) The patient, while standing erect, is told to bend his trunk backwards as far as possible. A healthy subject can do this, more or less, without falling by flexing the leg on the foot and the thigh on the leg, the knees being carried forward and the whole body curved backwards; but a cerebellar subject curves only the upper part of his trunk, his

legs remain immobile and vertical, with his feet fast on the floor, and he thus loses his balance. This is the reverse of what was observed when he started to walk, there being no synergia in the movements of the trunk and lower limbs. As closing the eyes does not affect this test, it cannot be confused with Romberg's test.

(*b*) If the patient is laid flat on his back, with his arms crossed on his chest, and is told to sit up, he cannot do so, but will raise his legs more or less from the ground, unlike a healthy subject, who will keep his heels firmly on the ground. This must not be confused with the combined flexion of the thigh and trunk, which is produced only on the paralysed side of a hemiplegic subject. If a cerebellar subject is examined, it will be found that the muscular energy is normal; this must be made certain before concluding from this test that it is really a case of asynergia.

(*c*) During the tests for hypermetria or dysmetria given above it will be observed that when the movements are carried out somewhat slowly they are not only exaggerated but detached, which is the characteristic of asynergia.

These asynergic disorders may occur unilaterally on the same side as the lesion, and this Babinski styles hemi-asynergia.

Intentional tremor.—During the foregoing tests for asynergia the examiner will observe whether there is *tremor* (the "intentional tremor" of Charcot), which is perhaps only a form of asynergia. When the tests of bringing the finger to the nose and the heel to the thigh are repeated several times the movement may be seen not to be in a direct, but in a waving line, the oscillations increasing gradually as the movement proceeds, and reaching their maximum at the end. The tremor is of great amplitude, extending to the

full length of the limb under test, but the intensity varies greatly in the same subject. It may even extend to the whole body, and especially to the head and trunk, or it may be confined to the limbs on one side only, and may be seen not only during the execution of a movement, but in the mere effort to maintain an attitude; then the tremor is both static and kinetic.

These are what Babinski describes as the essential symptoms to be found in consequence of lesions of the cerebellar apparatus; their relative importance naturally varying according to the subject, they must therefore be methodically looked for by the tests just described. It is not necessary to lay further stress on their great importance. It has been seen that hypermetria, asynergia, and adiadococinesia account for the difficulties of equilibrium and walking, and the combination of them will also explain the disorders of speech and writing found in cerebellar subjects.

Disorders of Writing.—The following tests should be carried out:—

(*a*) Tell the patient to make a dot with a pencil on a piece of paper; the patient will overshoot the paper with the pencil several times, but corrects himself, and finally succeeds in reaching the paper, when he will make a line of varying shape, but not a dot. This disorder arises from hypermetria, as in the test already given.

(*b*) The patient is told to trace a circle or to make a rounded capital letter, such as O or D. He will not make a continuous curve, but a polygon of a broken outline; this is combined asynergia and hypermetria.

(*c*) The patient is told to draw regular zigzags between two parallel lines; the lines will be irregular, often overshooting the vertical lines, and the angles

will be rounded instead of being acute. All these disorders will also be observable in the handwriting of a cerebellar subject.

DISORDERS OF SPEECH.—The speech is jerky, deliberate, explosive, and sometimes drawling or rolling. The explosive character is due to hypermetria, the deliberation rather to adiadococinesia. The intensity of these modifications varies greatly in different subjects.

C. Examination for Localising Cerebellar Cortical Symptoms

The researches of Bolk, Van Rynbeck, Rothmann, and André Thomas on animals, and of Barany on man, have enabled us to form the following theory of the physiological action of the cortex of the cerebellum:—

There are in the cerebellar cortex centres of muscular tonicity which furnish to the groups of muscles of the various joints the tonicity which maintains their attitude in repose by balancing the antagonistic muscles. During the execution of movements these centres supplement voluntary impulses by increasing the tonicity of certain muscles and diminishing that of the antagonistic muscles, which enables the movements to be correctly performed in a definite direction. They are therefore centres for the direction of movement, and in no wise motor centres. In each hemisphere of the cerebellum there is a tonic, and not a motor, representation of the musculature of the limbs and of the half of the trunk on the same side for each direction of movement of each articulation, which is situated in distinct and very limited regions of the cerebellar cortex. According to Barany, four such centres of direction can be distinguished in man: upwards, downwards, to right and to left, and the musculature of each articulation is represented in each

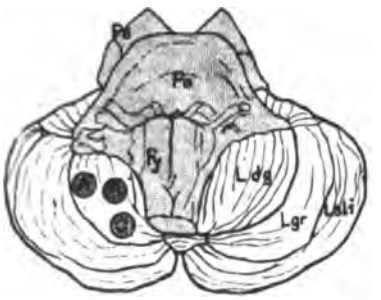


FIG. 36.—Anterior and inferior aspect of the cerebellum.

V

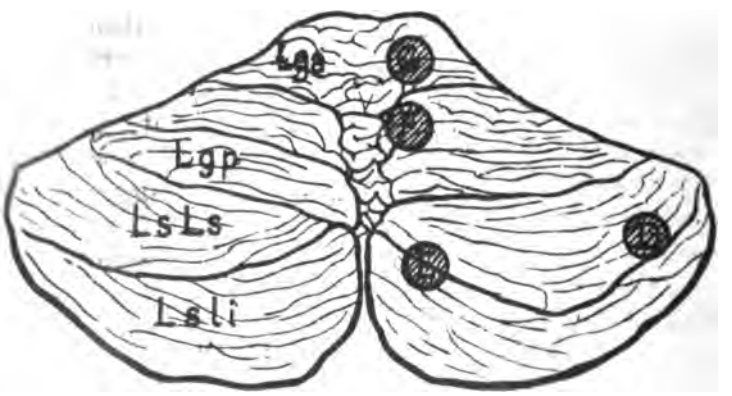


FIG. 37.—Posterior aspect of the cerebellum.

Cerebellar localisations.

Pe, Cerebral peduncle.
Po, Pons Varolii.
Py, Pyramid of the medulla.
Ldg, Biventral lobule.
Lgr, Slender lobule.
Lga, Anterior quadrilateral lobule.
Lgp, Posterior quadrilateral lobule.
Lsls, Superior semilunar lobule.
Lsli, Inferior semilunar lobule.
V, Vermis.

A, Centre for tonicity " inwards " of the hip.
B, ,, ,, ,, ,, arm.
C, ,, ,, ,, ,, hand.
(Destruction of these centres gives rise to a deviation of the arm outwards in the test for spontaneous deviation.)
D, Centre for tonicity outwards of the arm.
E, ,, ,, for lowering the arm.
F, ,, ,, of the muscles of the right half of the back (?).
G, ,, ,, ,, ,, ,, of the abdomen (?).
(The localisation of these two last centres is uncertain.)

centre. It is important to observe that this tonic influence of the brain on the musculature is largely of vestibular origin, and that it undergoes important variations under the influence of excitation of the vestibule (see Barany's tests).

These physiological data furnish a clue to the consequences of destruction of the cortical centres in the cerebellum. Destruction of a limited region of the cortex will cause: first, the suppression or the diminution of the tonicity of the muscles which come into play in the execution of the movement of a limb in a given direction; second, an exaggeration of the tonicity of the opposing muscles; in short, a loss of balance in the action of the antagonistic muscles, which is shown by: first, a modification of the attitude of the limb in repose; second, a modification of the passive movements, that is, exaggeration or diminution of the passive movements of the articulations in certain directions; third, a modification of the voluntary movements; and fourth, a modification of the cerebellar reactions in the limbs, normally provoked by excitation of the labyrinth (Barany's test). The more strictly the lesion of the cerebellar cortex is localised, the more clearly will these modifications be confined to certain muscular groups.

In practice the symptoms of defects in the cerebellar cortex can be elicited by examining the patient in the following manner:—

I. The Position of the Limbs.—Careful consideration must be given to the position of the patient's limbs in repose and in muscular relaxation, when erect and when lying on his back, comparing the position of the limb on the sound side with its fellow on the affected side; and the position of the head and trunk will likewise be observed. For instance, it may be seen that pronation of the forearm is more pronounced on the affected than on the sound side, or *vice versa*;

that the elbow is more markedly abducted or adducted on one side than on the other; that the right lower limb is in more pronounced external rotation than the left; that the head is inclined towards one shoulder, etc.; but the varieties of possible positions, according to the site of the wound, is so great, that it would not be of any interest to enumerate them. They can only be ascertained by a careful examination of the patient, especially when the wound has destroyed only a very small portion of the cortex.

II. Passive Movements.—Examination of the passive movements is of the greatest importance, and should always be carried out in conjunction with the examination of the voluntary active movements.

The passive movement tests (André Thomas) must be varied at discretion to suit the clinical aspect of each case.

1. Take hold of the patient's body with both hands, pull him sharply backwards and forwards, and note the extent of the oscillations of his upper limbs. This test may also be applied to the other limbs—the hand, the foot, etc.—in various directions.

2. Pull both the patient's arms from his body, and let them fall back; compare the manner in which the limbs fall back, and note whether there is any rebound when the arms strike the trunk.

3. Produce passive movements of pronation and supination, and compare the resistance to those movements on each side.[1]

The object of all these tests is to ascertain whether

[1] A detailed description of these tests as applied to two wounded patients will be found in a communication by André Thomas to the session of the Société de Neurologie on November 4, 1915. (*Revue Neurologique*, 1915, Nos. 23, 24, p. 1256.) Both these men showed a special modification of the tendon reflex,—"the pendulum type." That part of the limb affected by the attempt to elicit the reflex on the bad side described a series of oscillations like a pendulum, while that on the sound side rapidly returned to rest without undergoing any such oscillations.

the resistance to passive movements is diminished, normal, or increased in certain groups of muscles, that is, to make clear the deficiency in the tonic action of the cerebellar centres. It is essential that the patient shall be in as complete a state of voluntary muscular relaxation as possible during these tests.

III. Active Movements. Movements to Order.—A series of symptoms which will only become evident in the movements of certain joints in a given direction can be observed in these patients in the voluntary actions of everyday life and in the execution of movements to order. There will be slowness in carrying out movements on the affected side; the effort will not reach its maximum at the first attempt; the movement will be executed less quickly on the affected side. For instance, if the patient is told to place both index fingers on the end of his nose simultaneously, the index of the affected side will reach the nose after that on the healthy side; the speed of the movement will vary at the different stages of its execution; it will be too slow at the beginning and too hurried at the end, when its amplitude will also be exaggerated; there will be difficulty in stopping, and the mark will be overshot. This hypermetria, described above, may become evident only in the movements of a single limb in a single direction.

All these pathological modifications of the voluntary movements have already been described as they occur in various combinations, in the dysmetria, adiadococinesia, and asynergia of Babinski, and appear to be caused by extensive lesion of the cortex of the cerebellum and of the white fibres. But they may also be observed in the execution of isolated movements, such as the movements of a single joint in one definite direction, and then, in all probability, indicate a very limited lesion of the cortex. The

examination for these symptoms must therefore be protracted and minutely careful.

It will be useful to describe two more tests for ascertaining the modifications of the tonic innervation of the muscular groups in consequence of lesion of the cerebellum. (*a*) Stewart Holmes' test, or the test of the resistance. The patient is told to execute a movement, say, of flexion of the forearm on the upper arm; the observer resists the movement, and lets go suddenly. In the normal condition the movement of flexion will be completed, and there will be a slight rebound in extension; when there is lesion of the cerebellum, there will be no rebound. The same test can be applied to the resistance to flexion of the knee, the thigh, or the elbow. (*b*) Lotmar's test of the estimation of weight. Identical weights are put into the patient's hands simultaneously, and he is asked to say whether the weights are equal or not; if there is lesion of the cerebellum, the patient will say that the weight on the side of the cerebellar lesion is the lighter of the two. These two tests also show that the innervation of the antagonistic muscles is insufficient.

IV. Tests of the Cerebellar Reflex Movements of Vestibular Origin (Barany).—(*a*) *Spontaneous deviation of the index finger.*—If one of the centres in the cortex of the cerebellum has been destroyed, the suppression of the tonic innervation of certain muscular groups and the exaggerated activity of the opposed group can be ascertained by the deviation produced in certain movements to order. This is called the "Index test," and is carried out as follows: If it is desired to test the shoulder joint the patient is told to extend his arm, to rest it on his knee, on the same side, and then to touch the observer's index finger, which is placed in front of him; the patient must repeat this test three or four times with his

eyes open, and then continue with his eyes shut. Under these conditions a normal subject will continue the movement correctly, and touch the observer's finger each time; but if there is destruction of the centre for the tonicity of the inward movement of the arm the patient's finger, when his eyes are shut, will deviate outwards, and will no longer reach the observer's index finger. The deviation may be observed in all directions, and in any joint, according to the function of the centre affected.

In many cases this spontaneous deviation will not be observed, or, to speak more accurately, it only occurs when the lesion of the cerebellum is of comparatively recent date. A method has been devised by Barany for exploring the function of the centres of direction in the cerebellar cortex, and estimating their defect by means of the labyrinth if the spontaneous deviation does not occur. This is called the "test for incited deviation."

(*b*) *Test for incited deviation. Reflex movements of the limbs.*—Barany has proved that if stimulation of the vestibular nerve is provoked by injecting cold water into the auditory canal various phenomena are produced, among which are reflex movements of the limbs, which are deviated towards the side of the injected ear. For instance, if cold water is injected into the left ear of a normal subject, and the "index test" is applied to the different joints, it will produce a deviation to the left. Barany's theory, stated briefly and without the long details given by him, is that the execution of these movements by the brain is modified at the level of the cerebellum under the influence of excitation of the labyrinth; stimulation of the vestibular nerve on one side only provokes loss of equilibrium in the functions of the cerebellar cortical centres for the direction of movements, and deviation of all the movements of all the articulations

in the same direction is thereby produced. If one of these centres is destroyed the stimulus is not transmitted, and the deviation is not produced in one definite joint for one definite direction. By applying this "test for incited deviation" to each of the vestibular nerves in turn, and employing the "index test," or an analogous one, for the lower limb, the absence of deviation in one or several joints will be ascertained, and thereby the particular portion of the cortex which has been destroyed will be known. This delicate test is of the greatest importance, and must be repeated several times to enable a definite opinion to be reached. Its value has been proved by Barany in numerous clinical cases, which have been confirmed by operations or autopsies, and he was thus enabled to localise a certain number of centres for direction of movements of the articulations in man, which are shown in figs. 86 and 87.

It is necessary to apologise for the length of this description of the examination of a cerebellar subject, but it is only the superficial wounds of the cerebellum which enable us to define exactly the cerebellar localisations. Such wounds, therefore, require the profoundest clinical examination, which should be methodically conducted.

Site and Characters of Wounds of the Cerebellum

Speaking generally, wounds of the cerebellum are very seldom observed, which is due, we believe, to its being so close to the medulla, which is either injured at the same time, or is so affected as to cause immediate death from cardiac or respiratory failure, and not because such wounds are in themselves accompanied by damage sufficient to destroy life. According to the writer's personal experience, direct wounds of the cerebellum seem to be more rarely

seen than indirect wounds. By an indirect wound is meant damage to the cerebellum by a missile that has entered the skull anywhere except in the cerebellar area. Cases have been observed of wound of a cerebellar hemisphere by a rifle-bullet or shell-splinter which had entered at the vertex or near the fronto-parietal suture, the missiles being detected by radiography. Direct wounds are rare, because the cerebellum is protected by the nearly horizontal occipital bone and covered by thick masses of muscles, and so is not reached if the wound is slight; when the wound is severe and penetrating, it is most often fatal from shock, or from damage to the medulla, or laceration of the venous sinuses. Still, cases of superficial wounds of the cortex of the cerebellar hemispheres have been seen, and such few cases as have been available have been specially and most carefully studied by André Thomas, from whose description the following is taken.

Symptoms

Deep wounds, generally indirect.—As has been stated above, these are most frequently cases of penetration of a foreign body into a cerebellar hemisphere. The result produced is a cerebellar hemiplegia (Pierre Marie and Foix), with all the essential elements of the cerebellar syndrome: disorders of equilibrium and gait, hemiasynergia, hypermetria, and adiadococinesia on the same side as the wound. If the wound is in the occipital region, a deep lesion of a cerebellar hemisphere may sometimes be direct, but this is exceptional on account of the seriousness of the wound. If the patient survives, there will be found associated with the cerebellar hemi-syndrome disorders of vision due to lesion of the occipital visual centre, homonymous lateral hemiopia on the side

opposite to the wound, complete or incomplete hemiopia, and hemiopia in the superior quadrant. It has already been pointed out that the inferior portion of the visual centre receives impressions from the inferior half of the retina of each eye, and therefore its destruction entails defect of vision in the superior half of the field of vision.

Direct superficial wounds.—The localising symptoms (described under B, p. 713), which show abnormality of function in the antagonistic muscles, are found to a varying degree in these wounds. These troubles may be very limited, and confined to certain joints and certain directions. Two cases of this kind have been minutely and carefully studied by André Thomas.[1]

Recapitulating in general terms the symptomatology of wounds of the cerebellum according to the region of the cerebellum affected, and no longer considering whether the wound is deep or superficial, the following are the syndromes which will be observed :—

Lesions of the vermis: typical cerebellar gait with abnormal positions of the head; slowness in the movements of the head and face; troubles of speech; cerebellar asynergia in the trunk and, possibly, the lower limbs.

Lesions of one hemisphere: unilateral symptoms on the same side as the lesion, hemiasynergia, unilateral adiadococinesia, hemihypermetria; Barany's " index test " is abnormal for the upper and lower limbs on the side of the lesion, and in all directions if the lesion is important.

Lesions of the cortex alone: the preceding symptoms will be found again, but if the lesion is almost purely cortical, the tests for passivity will be found positive for only one limb, or for only one articulation; the test for spontaneous deviation is positive. Barany's " index test " will show sup-

[1] André Thomas *Revue Neurologique*, 1915, Nos. 23–24, p. 1256.

pression of the deviation in one direction of the movement, and only in one joint, according to the region of the cortex affected.

Lesions of the central grey cerebellar nuclei: injury of these appears to provoke principally serious vertiginous troubles of equilibrium (lateropulsion), abnormal positions of the head and trunk, catalepsy, and, perhaps, nystagmus.

Associated symptoms: injury of the cranial nerves (III., IV., V., VI., VII., and VIII.) do not belong to the symptomatology of lesions of the cerebellum. The nystagmus so often observed is probably not a direct cerebellar symptom, but is most frequently caused by action at a distance on the labyrinth such as is caused by tumours in the cerebellum; neither do the associated ocular paralyses (such as conjugate deviation, or paralysis of the associated lateral movements) properly belong to the symptomatology of the cerebellum.

Negative symptoms.—It is important to remember the absence of disorders of sensation and of alterations in the cutaneous and tendon reflexes in purely cerebellar lesions.

Course of Wounds of the Cerebellum

In general the symptoms caused by a wound of the cerebellum diminish regularly. The phenomenon of spontaneous deviation of the index only continues to be observable for a short time after the wound; the signs of asynergia and the hypermetria continue longer, but they finally appear only in certain movements, and the patient can make them cease altogether by keeping a watch on himself. The same is true of the disorders of the gait and equilibrium, which will only be observable when he makes an abrupt movement or a rapid half-turn.

The prognosis of wounds of the cerebellum, as seen at the base, is therefore favourable, and improvement appears to us in all cases to take place slowly but surely.

Differential Diagnosis

In the case of a direct wound of the cerebellar region the troubles observed are generally easily traceable to their cause. As a consequence of a wound of the vertex, it will be remembered that there will be observed spasmodic paraplegia of cortical origin together with troubles of co-ordination, which in most cases are due to the existence of serious alterations in deep sensation, and are of the ataxic type. There are much rarer cases in which modifications of the sensibility are not seen, but in which there are asynergic phenomena which will be detected in the way described above, and which probably arise from lesion of the cerebellum at a distance by "contre-coup." That essential organ, the labyrinth, is frequently injured in head-wounds, especially in the occipital region, and as the similarity of the symptoms makes the differential diagnosis particularly difficult, it will be useful to describe in detail the labyrinthine syndrome consecutive to wounds of the skull.

The Labyrinthine Syndrome following Wounds of the Skull

Lesion of the labyrinth may occur alone or with a lesion of the cerebellum. Injury to the labyrinth is shown by a group of symptoms which, in many points, resembles what is observed in cerebellar lesions, viz. kinetic and static troubles of the equilibrium.

The wound. — Lesions of the vestibular labyrinth may be consecutive to a wound of any part of the

skull, either by labyrinthine concussion at a distance, or more probably by way of a fracture, often very minute, extending from a wound of the vault to the base. On the other hand, direct wounds near the auditory canal, and especially about the mastoid, are accompanied by lesions involving both the cochlear and vestibular labyrinths, and the patients suffer from labyrinthine deafness. Only lesions of the vestibular labyrinth will be dealt with here, as lesions of the cochlear labyrinth, which entail more or less marked deafness, are in the province of the aurist. It may be added that lesions of the two labyrinths are pretty often dissociated.

Symptoms of Lesion of the Vestibular Appáratus

FUNCTIONAL SYMPTOMS.—These begin with vertigo of the most varied degrees of severity from mere obnubilation, provoked or increased by the movements of stooping, turning abruptly, or looking up in the air, up to fits of giddiness, in which the patient sees everything revolving around him, either towards the side of the wounded ear, or towards the opposite side; he sometimes falls, though he never loses consciousness. These almost constant vertiginous symptoms improve spontaneously, and do not last for more than a year.

OBJECTIVE SYMPTOMS.—Objective static troubles and disorders of locomotion are, in most cases, associated with the subjective sensation of vertigo, and it is most important to define them so as to distinguish them from their cerebellar analogues. Sometimes there is a slight swaying of the body when standing still and when walking, slight lateropulsion towards the side on which is the injured ear, and a broadening of the base of support. Frequently the patient, injured in one labyrinth only, walks *en échelon*;

when advancing towards a given point he swerves to one side after a few steps, which is repeated in the same direction again and again as he proceeds. Shutting the eyes causes an evident increase of the troubles of static equilibrium (the lateropulsion), which is not generally the case in a cerebellar subject. If the patient is blindfolded, and he is told to walk to a given point, he quickly loses direction, the angle of deviation being, to some extent, an index to the degree of his loss of the sense of direction (Babinski). Besides these symptoms, which can be ascertained by ordinary clinical methods, the condition of the vestibular labyrinth can be examined much more exactly by a series of tests which constitute the technique of the examination of the vestibular apparatus, and which every neurologist should be able to carry out and to interpret.

VESTIBULAR TESTS.—(*a*) *Examination for spontaneous nystagmus.* — Vestibular nystagmus is made up of two movements of the eyeballs, one slow, and the other abrupt. The nystagmus is named according to the direction of the abrupt movement, *i.e.* left, if the abrupt movement is made towards the left. This nystagmus appears when the eyes look straight forward; if the patient looks towards the direction of the rapid movement the nystagmus is increased, but it will disappear almost completely if he looks in the opposite direction. To elicit the nystagmus, make the patient look fixedly at an object, at least a yard from him, as looking at too near an object diminishes the nystagmus. Irritative lesion of the labyrinth sets up a nystagmus directed towards the affected side, while a destructive lesion sets up a nystagmus directed towards the opposite side. This spontaneous nystagmus is not a lasting sign, and generally disappears within a few weeks after the labyrinthine lesion. Nevertheless, before proceeding

to the tests now to be described, it is essential to observe the presence or absence of nystagmus. It is to be remarked that in some cases a nystagmus of very short duration can be provoked by abrupt movements of the head; by rotation to the right or left, or by turning it backwards, etc.

(*b*) *Rotary test.*—The technique of this test, which is only of comparative value, has already been described in Chapter I., where the results in the normal condition were stated. If there is destruction or impairment of function of one labyrinth, the duration of nystagmus of both kinds will be diminished, but to a much greater degree on the affected side. The disorder of equilibrium will also be much less marked on the affected than on the healthy side.

(*c*) *Barany's caloric test.*—The technique of this test has also been already described in Chapter I. When there is destruction of the vestibular apparatus, the caloric test, however long it may be continued, will not provoke reaction of any kind; if there is partial destruction, the reactions will be more or less diminished. Exaggeration of the reactions often occurs in syndromes of intra-cranial hypertension, and is frequently difficult to interpret. It must be understood that the terms exaggeration and diminution of the reactions are used only in reference to a comparison of the reactions of the affected ear with those of the sound one when tested under similar conditions. It must not be forgotten that unless the labyrinth remains excitable the reactional phenomena in the limbs, which have been described in connection with cerebellar semeiology (deviation of the index), will not be seen. The absence of deviation, of inclination of the body, and of nystagmus indicates destruction of the labyrinth, and prevents investigation of the cerebellar function.

(*d*) *Babinski's voltaic vertigo test.*—The technique

of this test has been described in Chapter I. If the vestibular lesion is bilateral, the resistance to the voltaic current is exaggerated (15 to 20 milliampères instead of 1 to 2), and there is a backward movement of the head instead of inclination and a rotation. If the lesion is unilateral, or predominant on one side, there will be unilateral inclination of the head to the side of the affected ear, whatever may be the direction of the current; more rarely the head is inclined towards the positive pole if it is on the affected side, but if the poles are changed over, the head will incline backwards. Other and less common changes have been observed. The rotation of the head in the voltaic test also undergoes modifications if the labyrinth is injured.

The modifications of the voltaic vertigo often bring to light very slight disturbances of the labyrinthine apparatus before the other tests described above have indicated any pathological change. During the application of this test the reactional movements of the limbs (index test), described in connection with the caloric test, and the lateral deviation of the body while walking, must likewise be observed.

It would occupy too much space to describe all the pathological modifications which may be observed in the course of this test, but they have been described in detail by Babinski and his pupils.

By this group of tests it is possible to ascertain exactly the condition of the vestibular labyrinth, and whether it is injured, even when there are no auditory disturbances, and also to distinguish the disorders which are due to the labyrinth from those which are due to the cerebellum in those which the patient presents. In fact, it is the only important differential diagnosis which can be made in cases of head-wounds presenting disturbances of co-ordination and of equilibrium.

CHAPTER X

ORGANIC LESIONS OF THE BRAIN BY CONTUSION AND CONCUSSION WITHOUT FRACTURE OF THE SKULL

General observations.—When a projectile strikes the skull it produces a concussion of the brain by a more or less violent disturbance of the whole mass of the brain, and simultaneously contusion of the nervous tissue at the point struck. The relative importance of the concussion and the contusion varies according to the force of the missile and the resistance of the bone. If the force is high, or the resistance of the skull is very low, there will be fracture with penetration of the projectile or of splinters of bone, and a wound of the brain. This latter eventuality is the most frequent in actual war, and the symptoms are those of "wounds of the brain," which have been described in the preceding chapters. Still, cases are often met with in which there are persistent symptoms of damage to the brain as a result of an injury to the skull, although local examination of the skull and radiography both fail to give any indication of fracture. These casualties are due to cerebral contusion. Again, there are cases in which there has been no direct injury, but the patient has been caught within the area of the explosion of a shell of large calibre and, although not struck by any

of the splinters, presents persistent and indisputable signs of an organic lesion of the nerve centres, sometimes very serious. These casualties are due to cerebral concussion.

In the following description only simple and typical cases have been purposely selected; in fact, such pure cases are rather rare, as there is generally both contusion and concussion simultaneously in varying proportions.

Cerebral Contusion

Symptoms

The symptoms of cerebral contusion are similar to those of any local superficial lesion of the brain, and do not differ essentially from those of direct wounds of the brain. After a period of shock or concussion following immediately on the injury, which only persists for a few hours and then completely disappears, there will be observed a whole series of localising signs which vary according to the seat of the contusion, signs of an organic lesion entailing a hemiplegia, a monoplegia, aphasia, hemiopia, etc. As all these have been described in connection with the wounds of the various regions of the brain it is not necessary to repeat them, but there is one special form of cerebral contusion to which attention must be drawn, contusion by "contre-coup."

Contusion by "contre-coup."—In all the cases which we have observed there has been a wound of the head with fracture and more or less extensive loss of bone in the region struck by the missile. In these cases the wound, although direct, had not caused any symptoms of cerebral organic lesion, but there have been indisputable signs of lesion at a distance, often in a region at a considerable distance on the opposite side to the wound.

The following clinical varieties have been observed:—

(*a*) *Wounds of the temporo-parietal region with hemiparesis or homolateral monoparesis.*—In these cases there was a hemiplegia or a slight monoplegia, with somewhat marked disorder of sensation, alterations in the tendon reflexes, and crises of partial Jacksonian epilepsy, all on the same side as the cranial wound, and therefore connected with a lesion of the opposite hemisphere

(*b*) *Wounds of the vertex with spasmodic cortical paraplegia and inco-ordination of a cerebellar nature.*—This variety has been described in Chapter IV. (Wounds of the Rolandic Area). They are probably cases of contusion of the cerebellum at a distance.

(*c*) *Wounds of the frontal region with lesions of the fundus.*—These complications of wounds of the frontal region have been dealt with in Chapter III. (Wounds of the Frontal Lobe). Besides lesions of the optic nerve by a fracture of the vault extending to the base, there are important lesions of the retina, radiating and irregular lacerations of the choroid and macula due to lesion of the eyeball by "contre-coup."

(*d*) *Wounds of the occipital region with radicular symptoms.*—In some cases of wounds of the occipital region there may be observed symptoms of irritation of the roots of the cervical nerves, shown by impaired movements of the upper limbs, especially marked on waking in the morning, a sensation of heaviness in the limbs, and of tingling or of numbness which the patient can provoke or increase at will by bending his head vigorously on his chest. In most cases there is tenderness on pressure over the cords of the brachial plexus, increase in the tendon reflexes, and paræsthesiæ, while electrical examination gives normal results. These symptoms can be explained by contusion at a distance of the upper medullary roots at the moment of the occipital injury.

It is important to be aware of the existence of these symptoms of a lesion at a distance by "contre-coup" in cases of head-wounds, and not to consider that the troubles complained of by the wounded man are purely functional. It must also be noted that in cases of wounds of the right temporo-parietal region there may sometimes be observed symptoms of aphasia which, most probably, arise from lesion of the convolutions of the left hemisphere by "contre-coup."

It is not necessary to dwell upon the pathogenesis of contusion by "contre-coup," as it can be explained by Duret's theory that a cone of depression of the cerebro-spinal fluid is formed at the level of the region directly damaged by the projectile, and a compensatory cone of elevation in the opposite region.

Cerebral Concussion

Symptoms

The type selected for description here is cerebral concussion consecutive to the bursting of a large projectile near the patient, as frequently happens in actual war, with results the gravity of which have not hitherto been suspected. These are cases of very severe indirect injury without any contusion or wound of the brain; in other words, pure concussion.

Immediate symptoms. — They may be summarised thus: immediate loss of consciousness (not always present); complete muscular relaxation; relaxation of the sphincters; slowing of pulse and respiration; low arterial tension; dilated or contracted pupils; epistaxis. A careful examination for some organic lesion has shown some observers that during this period there may be increase and inequality of the tendon reflexes, abolition or diminution of the

cutaneous reflexes, and the plantar cutaneous extensor reflex.

As a rule all these apparently grave symptoms rapidly pass off in a few hours and leave no organic trace behind them. But in some cases the organic nerve lesions remain and become localised, so that, when the patient is examined some months after the injury, various syndromes that have attracted the attention of several neurologists may be found.

Organic cerebral sequelæ of concussion. — We cannot enumerate them all,[1] and shall only mention the sequelæ that are undoubtedly organic: spasmodic hemiplegia (Guillain, A. Léri); hemiplegia with hemianæsthesia, due probably to a lesion of the optic thalamus (A. Léri); Jacksonian epileptic crises (Guillain, A. Léri); the cerebellar syndrome (Guillain, Rist); hematobulbia (A. Léri); lesions of the internal ear (often unilateral) with labyrinthine deafness, the prognosis of which is always very doubtful; lesions of the eyeball, and especially of the retina. We have also observed completely analogous cases. All these patients presented lesions of varying nature, but the symptoms observed prove them to be indisputably organic.

We shall not go into the question of traumatic general paralysis from concussion. Without wishing absolutely to deny to traumatism any possible influence in the development of general paralysis, we can only say that in the fairly large number of cases that we have met with the part played by traumatism in the production of the symptoms has never been beyond dispute.

[1] Consult André Léri, "Les commotions des centres nerveux par éclatement d'obus," *Revue générale de pathologie de guerre*, No. 2, p. 169, Vigot.

Diagnosis

The first point is, not to overlook the existence of a direct wound of the brain, whether the loss of substance is very small and a very small missile has penetrated very far from its point of entry, or whether the injury has caused a fracture of the base of the skull; radiographs should therefore always be taken and carefully studied. On the other hand, purely functional nervous happenings of an emotional or hysterical nature, or simply simulations of them, are frequently observed after a shell-burst. In these cases there are neuropathic crises, paraplegia, tremors, bilateral deafness, deaf-mutism, and aphonia, these nervous phenomena being much more common than true organic conditions. It is impossible to describe the differential diagnosis in each of these cases in detail; it will suffice to say that generally a methodical neurological examination, and repeated observation of the patient, will nearly always enable those who are really suffering from concussion with organic lesions to be distinguished from the false cases. In cases of organic concussion lumbar puncture will show either hypertension of the fluid, or evident hyper-albuminosis. But the best proof of the functional nature of the troubles will be their rapid improvement and cure under proper treatment.

Pathogenesis

Only the macroscopic lesions actually observed in the course of the present war are dealt with here, although before the war numerous researches had been carried out on the microscopic lesions observed in experimental concussion.

The existence of disseminated hæmorrhages in the meninges, in the cerebral cortex, and even in the

depth of the brain has been ascertained, and much more rarely there have been cases of disseminated foci of softening without hæmorrhage.

In the cases of pure concussion which have been selected as types for description (concussion resulting from the explosion of a large projectile), certain authors are of opinion that the gases violently compressed by the explosion ("wind of the explosion") act like a solid projectile on the skull and brain. Others compare these organic accidents consecutive to concussion to the symptoms due to too rapid decompression in "caisson-sickness" (release of the gases of the blood, and gaseous emboli with rupture of the capillaries and hæmorrhages). They consider that the decompression of the atmosphere which is produced after the explosion of a large projectile acts on the nervous centres in the same way.

Probably each of these theories contains a part of the truth, and the pathogenesis of nervous lesions due to concussion is not susceptible of a single explanation.

In conclusion, it may be noted that cases of concussion of the spine with organic lesions are much more numerous than those of concussion with cerebral changes.

Complications of Wounds of the Brain

CHAPTER XI

MENINGITIS

We shall not deal with the acute meningitis which is observed for a few days after the wound, but shall consider the meningitis that occurs later: this may occur in various forms.

Symptoms

There is a slight but persistent suppuration about the scar in the scalp, and a radiograph shows the presence of splinters in the immediate neighbourhood of the wound and at a considerable distance below it; the wound continues to suppurate for several weeks, and the infection extends insidiously to the meninges.

Clinical Forms

Encysted meningitis.—In some cases there is not at first a diffuse meningitis. The wound being several months old has produced adhesions between the dura mater, the pia mater, and the superficial soft parts; the damaged area is limited, and an encysted meningitis occurs on the convexity of the hemisphere; all degrees may be observed from encysted serous

meningitis to a suppurative meningitis constituting a true dural abscess. Local symptoms of irritation are observed, with signs of compression indicated by a moderate increase in the intra-cranial tension. In this variety very careful surgical intervention may yield the best results.

Diffuse meningitis over the convexity and at the base.—This form may follow on after the one just described, but it more usually appears independently, and may come on several months after the wound. The point of entry of the infection may be at the level of the nearly healed wound. It seems, however, that in these varieties of diffuse meningitis the point of entry of the infection should rather be looked for along a fracture of the base which has involved the middle ear or the frontal sinus. This is the classic form of meningitis consecutive to fractures of the base of the skull. It is not necessary to describe in detail the clinical picture of acute diffuse meningitis, as it has no features specially connected with wounds of the brain. But special emphasis must be laid upon the importance of lumbar puncture in the diagnosis, and also as the only means of relieving a patient whom there is but little hope of curing.

Ventricular meningitis.—This somewhat special form is by no means uncommon in wounds of the brain. It may be even said to be the form peculiar to them. It is the culmination, or the almost certainly fatal complication, of abscesses of the brain which have not been operated upon, but it may be seen apparently as a primary affection. It begins with extremely violent headache accompanied by vomiting. The phenomena of excitement observed in meningitis over the convexity are but slightly marked, and the patient very quickly becomes drowsy, and soon afterwards comatose. The modifications of the respiratory and cardiac rhythm are often very marked, and visual

troubles, such as diminution of the visual acuity and optic neuritis, are common. Somewhat intense glycosuria is not uncommon. The temperature rises rapidly, almost without matutinal remission, and the patient survives only a very short time.

In the cases we have observed there was a very small abscess situated near the wall of the ventricle which had given rise to no appreciable symptoms. Either by contiguity or by rupture of the abscess the infection had entered the ventricle, and there was a thick purulent layer attached to the ependyma of the ventricles, more especially the fourth. It is important to be acquainted with this form of meningitis on account of the extreme seriousness of the prognosis and its very rapid development.

The treatment of this delayed form of meningitis calls for no particular remark. In the encysted form surgical intervention is indicated, and may be useful. In the form of meningitis complicating an abscess of the brain which has been diagnosed and localised, surgical treatment of the abscess should be carried out even if lumbar puncture yields a turbid fluid. In meningitis of the ventricles we believe that all treatment is powerless, but lumbar puncture, carefully employed, may relieve the patient.

CHAPTER XII

ABSCESS OF THE BRAIN

Causes

It is the custom to say that any wound of the skull, or even of the scalp, may be the starting point of a cerebral abscess. In actual fact the more or less penetrating and irregular wounds of the skull, which go on suppurating for a long time, are the most common cause of abscesses. It is the small and irregular fractures, much more than the large losses of substance, which get complicated with cerebral abscess. Such fractures are accompanied by little splinters which penetrate more or less deeply into the brain. It is not so much the splinters, nor even the missile, which are chiefly to blame for the formation of an abscess, but the shreds of clothing and hairs carried in by the projectile. The wound often cicatrises very rapidly; the importance of the cerebral lesion is not recognised, and it is thought to be surgically cured.

The abscess develops either very superficially immediately under the bone defect, or else very deeply in the white matter of the hemisphere. In the former case it is most frequently, but not always, an acute abscess; in the second, the abscess develops slowly, a long time after the receipt of the wound.

Symptomatology

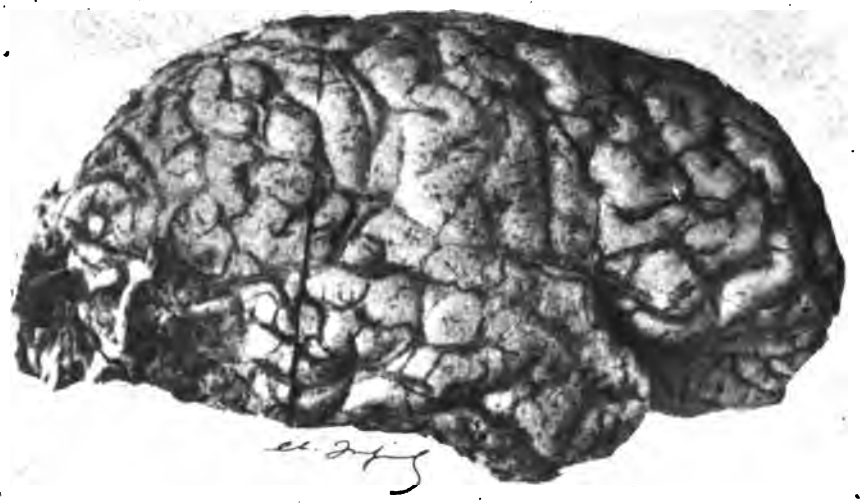
I. Acute Superficial Abscess

It is not necessary to dwell at any length on this variety, which is generally observed during the first few weeks after the injury, and is generally superficial, rapid in development, and in the immediate vicinity of the wound.

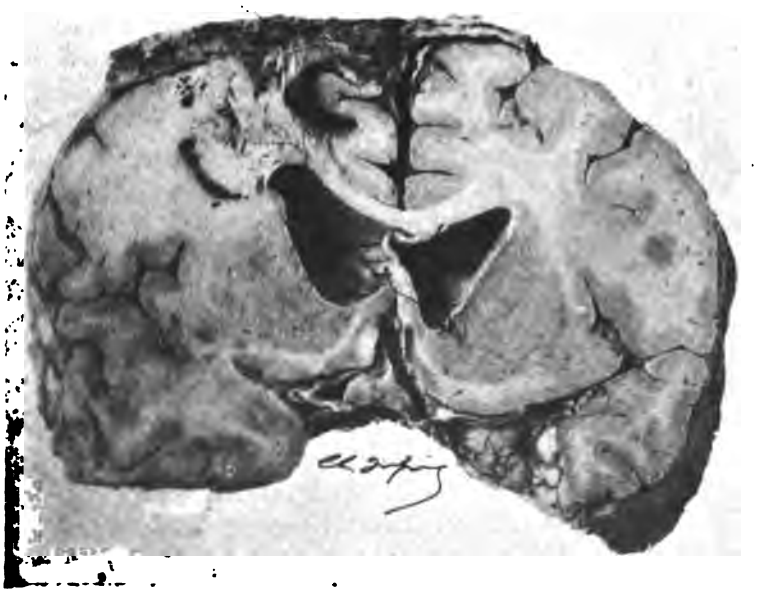
The symptoms directly due to the abscess are generally masked by the clinical phenomena arising from the head injury, which is itself often complicated by a diffuse meningitis developing at the same time as the abscess. This is especially the case when the abscess develops within a fortnight after the injury.

As a rule the abscess, even when acute, hardly develops before the end of the second or third week, and if the symptoms directly due to the wound have improved, the onset of suppuration shows itself by a group of meningeal symptoms, such as severe headache, pyrexia, vomiting, vertigo, delirium, or prostration, exactly like that at the onset of diffuse meningitis, but distinguishable from it by certain peculiarities, such as the absence of rigidity or Kernig's sign, the absence of cutaneous hyperæsthesia, a comparatively low temperature, and a slow pulse. The localising signs, however, generally appear rapidly, and become the most prominent, especially if the abscess is forming about the rolandic area. This accentuation of the localising symptoms proceeds somewhat slowly, and often with intervals of remission.

If there is no intervention the general signs become accentuated, as well as the symptoms of increased intra-cranial tension and diffuse meningitis, which foretell a quickly fatal result. This alternation of meningeal and local symptoms and their compara-



Area of encephalitis at the apex of the right occipital lobe after a bullet-wound. Complete left homonymous lateral hemiopia.



Area of encephalitis on the right parietal lobe extending up to the ventricle, simulating a cerebral abscess.

PLATE I.

tively slow development sometimes allow the surgeon to make a correct diagnosis, and to appreciate the fact that the case is not merely one of generalised meningitis, and so enable him to intervene in time and open and drain the abscess.

It is, however, the chronic abscess which has the greatest interest for the neurologist.

II. Deep Chronic Abscess

The general symptoms become evident after the wound has been cicatrised for several weeks or months, and when the local symptoms due to lesion of the brain have completely disappeared or become stationary. There is first a modification of the general health, shown by emaciation; loss of appetite: slowness of digestion; constipation; disordered condition of the digestive tract; more or less pronounced pallor of the skin and mucous membranes; cold sweats, sometimes accompanied by shivering; and, finally, an occasional slight rise of temperature (a few tenths of a degree only); this, however, is by no means always so, and in the majority of cases there seems to be a tendency for the temperature to be subnormal. Cerebral symptoms due to increased intra-cranial pressure make their appearance simultaneously with these general symptoms. Headache is nearly always present, but its intensity varies greatly; often very slight and periodical during the period of latency, it may become extremely severe when the abscess reaches a certain size, coming on in regular paroxysms, and provoked by anything which increases the vascular pressure in the brain, such as coughing, sneezing, or stooping. As a rule it is generalised, but its maximum intensity is on the same side as the injured hemisphere, and the patient complains of feeling as if his head were bursting or

being crushed. It is quite different from the neuralgic type of headache described above in connection with wounds of the skull without symptoms of cerebral organic lesions. Nothing relieves it, but it seems to become milder as the case develops, and the patient becomes drowsy and dull before the onset of coma. It is not necessary to dwell on the vomiting, the sensations of vertigo, the slowing, and sometimes irregularity, of the pulse, which persists even where there is pyrexia.

Papillary stasis is a very important symptom of increased intra-cranial pressure which may be found in these cases, but not so regularly as in cerebral tumours; it only occurs with very large abscesses which develop extremely slowly, and at an advanced stage.

Psychic troubles, with the exception of aphasia, are nearly always found at some period. The patient cannot follow a conversation, and replies slowly and distractedly as if just waking from a dream; his mental operations are performed extremely slowly, and are accompanied by a sensation of great fatigue; soon the patient passes into a condition of permanent drowsiness, so that he has to be shaken in order to elicit vague replies to the questions put to him, and this drowsiness becomes a continual sleep or true coma towards the end of the illness. Excitement and incoherence in language and gesture are seldom seen except at the beginning of the case. Convulsions are comparatively rare, but they may be observed in the final stages, especially if the abscess bursts on the convexity of the brain or into the ventricles.

In addition to these general symptoms there are localising signs, which vary greatly according to the seat of the abscess, and which it is not necessary to recapitulate, but which sometimes do not appear

Two abscesses on the left temporal lobe consecutive to a supra-mastoid wound ; considerable œdema of the whole hemisphere. Syndrome of intracranial hypertension such as is observed in cerebral tumour.

PLATE II.

at all. These signs may become evident even when the injury may have shown no sign of cerebral lesion, or in spite of any such signs having entirely disappeared. For instance, a patient with a hemiplegia from a wound in the rolandic area which has left only trifling sequelæ may develop symptoms of a progressive and rapidly increasing hemiplegia or monoplegia; or to the stationary original symptoms there may be added new symptoms, such as sensory disturbances, hemiopia, etc.

There is one very important symptom pointing to the formation of a cerebral abscess which may be found when the abscess is in the occipital lobe if the field of vision has been thoroughly examined. If the patient presented a hemiopic scotoma, or a quadrantic hemiopia before the formation of the abscess, there will be a rapid aggravation of these symptoms, and a complete hemiopia will take the place of the scotoma.

Clinical forms.—We desire to call special attention to two clinical forms of cerebral abscess observed by us which seem to be somewhat opposed in their manner of development. The abscess may develop like a cerebral tumour, without any modification of temperature, or only with signs of slowly progressive increase of intra-cranial tension; persistent headache, vomiting, and marked papillary stasis, accompanied by rapid diminution of visual acuity, culminating in almost total blindness. Plate II. shows a brain with an abscess of this variety.

In another case the patient, who had been apparently well for several months, developed symptoms of acute ventricular hypertension, with pyrexia, retraction of the neck, Kernig's sign, rapid diminution of the visual acuity without papillary stasis, and rapidly died. In this case there was a small abscess very deeply seated near the ventricle

which had caused intense ventricular meningitis. These two cases are given to show how difficult the diagnosis of a chronic abscess in the brain may be in certain cases.

Differential Diagnosis

The practical question to be decided is whether there shall be surgical intervention or not, therefore it is essential to make quite sure whether there is a generalised meningitis or a focus of encephalitis or an abscess. In the first case, intervention is nearly always useless; in the second case (chronic encephalitis), it is fatal; and it is only in the third that immediate operation is justified.

(*a*) A differential diagnosis between an abscess and meningitis is seldom called for except in the case of the early superficial abscess of acute development; if the wound is several months old it is no longer a question of a differential diagnosis, but of a diagnosis of complications, *e.g.* whether the abscess is complicated by generalised meningitis. If that is the case, the pyrexia, the rapid pulse, and the replacing of localising symptoms by those of meningeal irritation, together with the results of lumbar puncture, will clear up the diagnosis.

(*b*) Besides generalised meningitis, an abscess has to be distinguished from certain other less common cerebral lesions, such as traumatic apoplexy, and especially hæmatoma of the dura mater consecutive to a wound. This generally becomes evident during the first few hours after the injury, but there is a variety known as late traumatic apoplexy, which may not appear till several weeks after the wound. The seat of this is fairly characteristic, as it manifests itself by signs of localised lesions of the pons and medulla, and therefore by quadriplegia, dysphagia,

dysarthria, and pretty often by a homolateral hemiplegia. Its course is fatal, and often very rapid.

(*c*) The last question is whether it is possible to mistake a traumatic abscess of the brain for a purely functional group of symptoms such as those we have described at the beginning of this work. It does not seem possible; the only common symptom is the headache, but the characters of the headaches in the two cases, as well as the organic symptoms accompanying a cerebral abscess, have been so fully described, that there should be no possible doubt in the matter.

CHAPTER XIII

EPILEPSY

Epilepsy from a Wound of the Brain

EPILEPSY is neither a constant, nor even a very common, complication of wounds of the skull. The statistics of the cases we have examined show about 8 per cent. of such cases.

True epileptic fits may occur as a sequel to cerebral concussion, without any wound of the skull. Such an occurrence is rare, but it is important to remember.

It generally comes on six to eight months, but sometimes eighteen months or two years, after the wound, which may be entirely cicatrised by that time; in some cases, however, it is observed soon after the injury, or at the time of a surgical operation, such as trephining, performed several months later. The attacks may assume the form of the classical grand mal or any of the varieties of petit mal.

No correlation has been observed between the seat of the wound and the appearance of epileptic attacks; not only wounds of the frontal or rolandic areas (the latter, however, more often give rise to Jacksonian epilepsy, or to true epilepsy beginning as the Jacksonian variety), but also occipital, and even cerebellar, wounds may cause them. Neither has there been observed any peculiarity in the objective characters of the wound nor the presence of foreign bodies in

the brain, which will explain the appearance of these attacks. Whether there is loss of the substance of the external table only, or a depressed fracture of the inner table, or a deep or a very large wound, the attacks may come on and be of the same type as a generalised fit. It is therefore impossible to say exactly why certain wounds of the skull and brain are accompanied by epileptic fits after an interval of a few months. It is very probable that there is encephalitis with meningeal adhesions, but this is usually found in all the cases of wounds of the brain verified by a post-mortem.

We wish to lay stress on the fact that, in the seventy-five cases in which there was a projectile retained in the skull and which came under our notice, there was no case of epileptiform fits. On the other hand, we have made necropsies on three patients who were the subject of traumatic epilepsy, in which we found areas of encephalitis but no retained foreign body. Similarly, in the numerous radiographs of cases of traumatic epilepsy that we have had taken we have never found a retained projectile in the brain.

The fits come on at varying intervals, once a month or every two or three months. As a rule the intervals are fairly long; but the cases have not yet been long enough under observation for an opinion to be formed as to the course of this complication, and it is impossible to say definitely whether there is a spontaneous tendency to extension of the intervals between the fits, and whether they will finally disappear. It must also be remarked that treatment by bromides does not appear to modify them much.

Surgical treatment does not appear to give any permanent results. In some cases it seemed that the presence of splinters imbedded in the dura mater might have had an important influence in precipi-

tating the fits; after operation we have seen the intervals between the fits (which had been very short—several a week) get manifestly longer, but the fits have not disappeared altogether.

As a military doctor is often called upon to decide whether the fits from which a patient suffers are neuropathic or really epileptic, it will be useful to recapitulate briefly the characters of grand mal as well as the principal aspects of petit mal.

The Epileptic Fit

Prodromata.—The aura is the first symptom of the fit, and is extremely common. Several varieties are distinguished — the sensory aura: a visual, auditory, gustatory, or olfactory hallucination; the sensitive aura: a sensation of cold or burning in some part of the body, precordial pain, headache, epigastric heat, etc.; the motor aura: tremor of one member or paresis, muscular cramps; the vasomotor and secretory aura, and the psychic aura. The aura lasts a few seconds, and is immediately followed by the convulsive stage.

The convulsive stage.—The patient emits a scream or cry, and immediately collapses on the ground unconscious and helpless; the skin is pale, and the tonic spasms immediately appear. The features are drawn, the head is turned backwards, the eyes are wide open, the pupils dilate and do not react to light, the jaws are clenched, the arms are rigid, the fists are clenched, the lower limbs are extended, and the respiration is arrested. This tonic stage lasts a few seconds, at the most half a minute. Then comes the clonic stage. The pallor of the integuments is succeeded by a more and more marked cyanosis, prolonged rapid and irregular contractions occur in all the muscles, the tongue is protruded between the teeth

and often bitten, the breathing is irregular and laborious; the patient, still unconscious, becomes stertorous, and a more or less abundant and often reddish froth comes from the mouth. The countenance is swelled, and becomes increasingly purple, and the veins of the neck dilate. There is frequently an involuntary emission of urine and fæces. Then after a varying period the spasms become less frequent and less violent, and become localised in certain groups of muscles; the breathing becomes more regular, deep and full, the cyanosis abates, and the skin becomes paler, and is covered with an abundant sweat. Finally the spasms cease, and the patient falls into a profound sleep, with complete muscular relaxation, and snores. The patient remains totally unconscious throughout the fit. On waking he is exhausted, depressed, and bewildered, answers slowly and with difficulty, and presents signs of sensory or muscular exhaustion amounting to paresis of certain groups of muscles, and there may be observed areflexia or exaltation of the tendon reflexes, with or without Babinski's sign.

"Petit Mal"

The most usual form is epileptic vertigo. After, or without, a short aura the patient turns pale, his gaze becomes fixed, his respiration stops, he abruptly becomes immobile, and allows anything he may be holding to fall out of his hand, and makes some spasmodic movements. Then in a few seconds his breathing returns, his eyes turn to right and left, he continues his conversation where he left off, and resumes his occupation; he remembers absolutely nothing, but feels uneasy, or evinces a desire to sleep. Besides this typical form of petit mal, the most varied forms may be seen, and of the slightest character, such as a mere suggestion of the aura and nothing

more, vertigo, a sudden and brief sensation of oppression, headache of a mild form, various vasomotor troubles, passing dimness of the sight, etc. It is important to know these very mild forms of epilepsy, and to refer them to their true cause.

The Status Epilepticus

It sometimes happens that wounded men who are to all appearances cured suddenly pass into a true status epilepticus, consisting of fits of general epilepsy supervening on a state of apparently perfect health, or preceded only by twenty-four or forty-eight hours of persistent headache. The fits recur at intervals of a few minutes; the patient becomes comatose, bathed in sweat, and with marked pyrexia. The reflexes are exaggerated, and there is often bilateral extension of the toe. Death supervenes in twenty-four to forty-eight hours in spite of treatment. In the three cases we have seen, lumbar puncture showed moderate lymphocytosis with hyperalbuminosis. It is very important to know this form of epilepsy supervening on wounds of the brain which are apparently cured. It may lead to an erroneous diagnosis of diffuse meningitis or of abscess of the brain, and the medical man may be tempted to have recourse to surgical intervention. In all cases which have come under our observation, and in which there has been a post-mortem examination, there has been a focus of traumatic non-suppurative encephalitis, the focus corresponding in area to the whole extent of the loss of bone, and extending in depth to the ventricle. There was neither meningitis nor localised suppuration, and surgical intervention would have been perfectly useless.

Diagnosis

The question always arises when a patient says that he has fits whether they are true epileptic or purely neuropathic fits, and sometimes the only possible way to answer it satisfactorily is by personal observation of a fit, as interrogation of the patient will only yield the elements of a diagnosis of probability.

The true epileptic fit has the following essential characteristics: The aura, then unconsciousness throughout the fit, biting the tongue, involuntary emission of urine, a very short duration of the fit itself, which is followed by sleep.

The purely neuropathic fit, on the contrary, is of long duration. The patient cries out, rolls on the ground, speaks, sees the people surrounding him and speaks to them; he frequently remembers the fit, and when it is over he recovers much more quickly. The picture of the neuropathic fit is much more dramatic than that of true epilepsy. But in spite of these points of distinction it will often be difficult to make a definite diagnosis, and the only sure guide is the observation of a fit by the medical man.

The numerous varieties of petit mal are often very difficult to identify, as patients suffering from wounds of the skull very often complain of subjective troubles, such as headache, giddiness and vertigo, which also occur in the slight forms of petit mal, and in such cases a correct diagnosis can only be made by prolonged observation of the patient.

Jacksonian Epilepsy

Jacksonian epilepsy is frequently, but not always, observed in connection with wounds of the rolandic

area. The conditions under which the phenomena appear are the same as in true general epilepsy, and the same patient may have a Jacksonian convulsion which ends in a general epileptic fit with loss of consciousness; or general epileptic fits may succeed the Jacksonian ones, or may alternate with them. There is every intermediate degree between the pure Jacksonian attacks and pure epilepsy.

Symptoms.—The attack consists essentially of involuntary clonic spasms limited to certain definite muscular groups which generally come on without an aura or an initial cry, the patient remaining perfectly conscious of what is going on. The distribution of the muscular spasms is more or less limited, their duration is very variable, and their extension is more or less great. They may be strictly localised or may extend progressively, but in each patient they always start in the same group of muscles, and always develop in an order determined by the anatomical arrangement of the motor centres of the cortex. For instance, if the spasms begin in the face, they will spread immediately to the upper limb and then to the lower limb on the same side; if they begin in the upper limb, they will spread simultaneously to the face and to the lower limb on the same side, etc., finally spreading to the other side of the body. This however, is merely the general rule; the spasms may remain strictly confined to the groups of muscles in which they began.

The clonic spasms rapidly increase in intensity and end in a tonic stage of very short duration, and then the clonic spasms reappear. The fits may be repeated at very short intervals, and their duration is very variable: they are generally almost identical in development. The patient does not lose consciousness in pure Jacksonian epilepsy. There is one very interesting fact which it is important for both the

patient and the medical man to know: the fits are independent of the will, and cannot be voluntarily arrested; but if, as soon as the first spasms appear, the patient or the doctor firmly presses that part of the limb in which the first spasms appear (the forearm, or toes, etc.), the convulsion may be completely aborted.

Sequelæ.—If the fit has been severe it is frequently followed by a paresis of the muscles affected by the spasms, with alterations in the reflexes, and this lasts for some minutes or hours. If the Jacksonian convulsion occurs in muscles already paralysed, it will be followed by an increase in the paralytic phenomena.

Sensory Jacksonian epilepsy.—Besides the pure motor form of Jacksonian epilepsy there is another which has been described as sensory Jacksonian epilepsy. The patient feels a sensation of tingling or numbness in the extremity of a limb, and this may increase to complete anæsthesia, and may extend to the root of the limb and involve the rest of that half of the body, the attack lasting for some minutes. Various modifications of sensation in this part of the body may occur for some hours after the attack.

Differential Diagnosis

There can be no hesitation with regard to the pure Jacksonian epilepsy, but in patients with wounds of the brain certain special spasmodic phenomena may be observed which must, we think, be distinguished from Jacksonian epilepsy. These are the myoclonic or pseudo-myoclonic fits seen in those with wounds of the rolandic area. These myoclonic, or apparently myoclonic, spasms occur in the muscles of the limbs on the side which has been previously paralysed. They are exaggerated or provoked by the

patient putting the affected limb in a state of muscular tension by stretching the arm or leg, for instance, and they persist as long as the attitude is maintained. They occur irregularly in certain groups of muscles, and are strong enough to cause slight movements of the limb. The spasms are increased if the muscles are percussed with the plessor. The pathogenesis of this phenomenon is very obscure. It is possible that the spasms may be due to irritation of the cortex in the region of the wound, and are therefore nearly akin to true Jacksonian epilepsy. There is a somewhat rare form of epilepsy called myoclonic epilepsy, in which the true epileptic fits alternate with periods of persistent and generalised myoclonic spasm.

CHAPTER XIV

FOREIGN BODIES IN THE BRAIN

THERE may be fragments of the cap, the scalp, the skull, or the missile carried into the brain. The two former are not visible, as they cannot be shown by

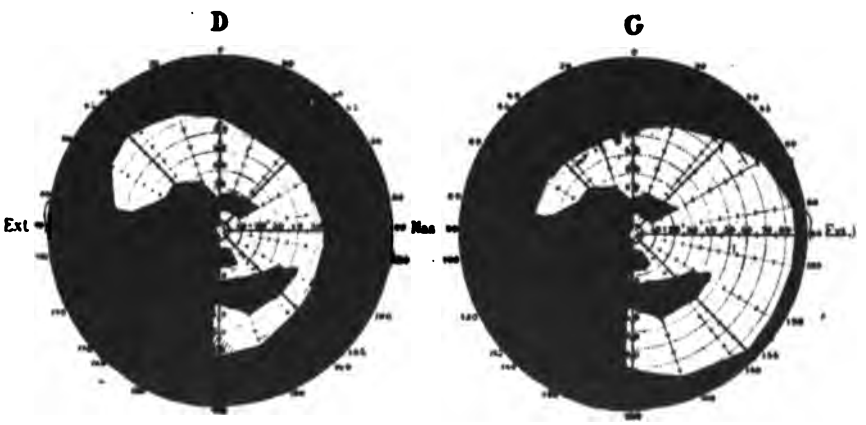


FIG. 38.—Complex defect of the visual field consecutive to intra-cerebral penetration of splinters (*cf.* following radiograph). Hemiopia in right inferior quadrant with three congruent hemiopic scotomata in the left half of each visual field. Operation with the object of extracting the splinters would be extremely serious, and could only increase the visual defect.

radiography, but they are, in our opinion, the most important, because they carry infection. The bone fragments come from the whole thickness of the skull when the wounds are penetrating; if they are

tangential, the external table may be almost intact, while the internal table is split into minute fragments which are often carried far into the substance of the brain. These splinters are of all shapes and sizes,

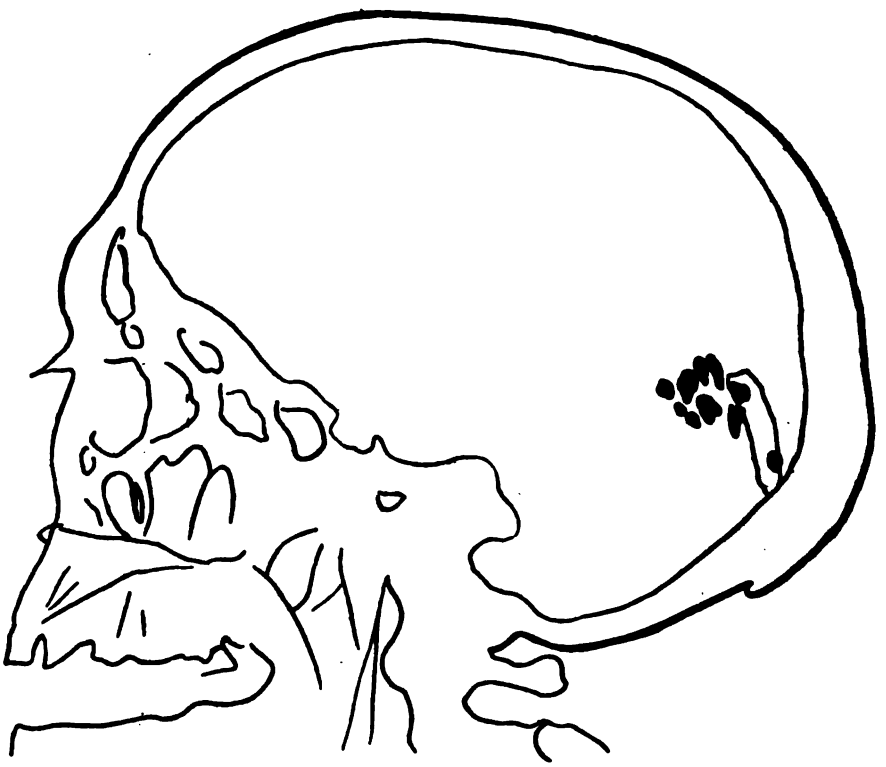


FIG. 39.

and are often only perceived by the aid of a radiograph (and it must be a very good radiograph too).

Out of about 3000 head cases we have found missiles in the brain in 75. In the cases in which the injury was at least several weeks old the skin wound in the great majority had been healed for some time.

The missiles that have come under our notice have been almost exclusively shell- or grenade-fragments

of varying size and dimensions, some of them measur-

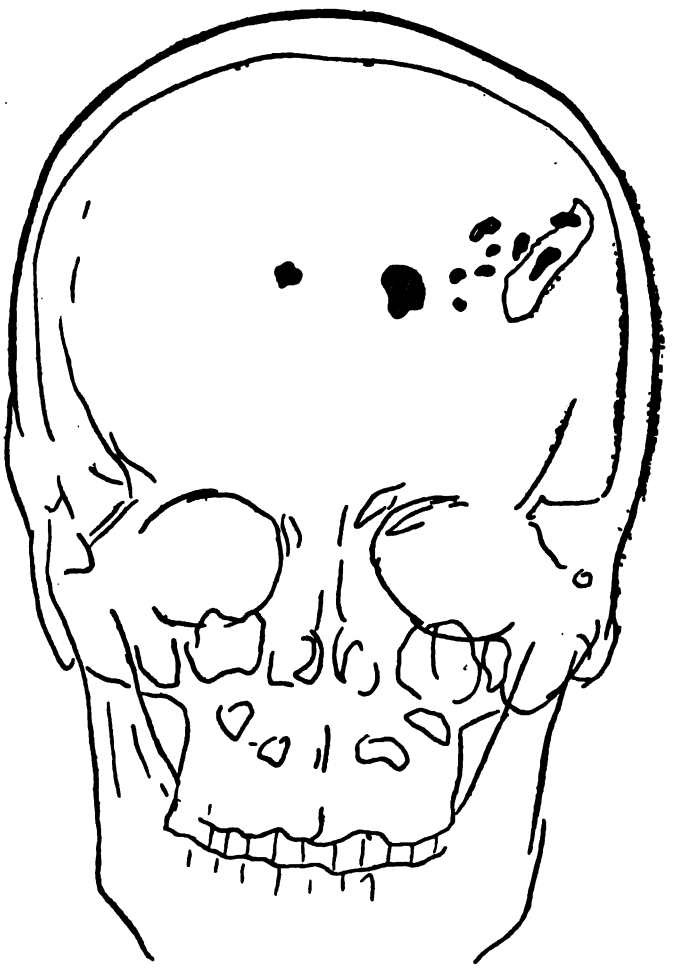


FIG. 40.

FIGS. 39 and 40.—Radiograph of the skull (full face and profile), showing the loss of bone, with numerous splinters (shaded) in the depth of the left occipital lobe and almost in the right occipital lobe (Author's case).

ing on the radiographic plate as much as an inch in diameter. In the 75 cases alluded to above there

were only six shrapnel balls and three or four rifle or machine-gun bullets.

In the majority of the cases the projectile, whatever had been its point of entry, was situated in an area that could be marked out in a lateral view of the skull by a vertical line drawn upwards from the external auditory meatus, and a horizontal one joining the latter orifice to the external occipital protuberance.

The foreign body was situated either entirely in the white matter or, fairly frequently, in the median vertical plane close to the falx cerebri, which, in a certain number of cases, seemed to have arrested its progress.

In a large number of cases the diagnosis of a projectile in the interior of the brain was arrived at owing to a want of correspondence between the seat of the opening in the skull and certain localising cerebral symptoms, such, for instance, as a complete hemiplegia of the capsular type coinciding with a wound in the frontal region (fig. 12), or perhaps a hemiopia occurring after a wound of the vertex (Chapter VIII.).

But it is very important to note that in all these patients the symptoms are those actually due to the mechanical damage done by the missile as it passes through the brain matter. Therefore, if the former in its course, which is often a long one, has given rise to symptoms referable to the division of certain groups of fibres, it must not be supposed that these symptoms are in any way related to the prolonged sojourn of the body in the brain substance, nor that it is a question of complications due to its presence there.

All the cases that have come under our notice went about without experiencing the least inconvenience from the presence of the projectile within their brains, so much so that they were quite ignorant of the fact that they had such a condition.

Without the aid of radiography it would have been

impossible to discover the existence of the foreign body. We may here recall attention to the fact that one can only judge of the position of the latter by making use of two radiographs, one antero-posterior and the other lateral. Without this assistance there is always the danger of mistaking for an intra-cerebral projectile one lodged in the thickness of the skull or situated beneath the orbit, or in one of the bony sinuses.

This being so, we are of opinion that, *given the absence of any infection*, an intra-cerebral projectile does not, *per se*, cause any risk to the patient. Therefore we cannot admit the principle that every foreign body in the brain should be removed, in face of the abundant evidence of the innocuousness of non-septic foreign bodies. Even the most careful surgical intervention has led to disasters in several cases in which the projectile had remained absolutely quiet and inoffensive. In any event, operation, by dividing fresh nerve fibres, adds to the damage already existing, and is likely to add to the patient's troubles.

We are of opinion that, in the case of a foreign body in the brain, no surgical interference is required unless this should be called for by some special symptom pointing to infection.

There will always be time to do this if a minute examination of the neurological condition of the patient is frequently carried out. We would go further and say that the presence of a foreign body renders the search for an abscess, should one arise, much more easy, thanks to radiography, and thus avoids damage likely to be caused by blindly groping about for it without the direction that its presence affords.

PART II

WOUNDS OF THE SKULL

CHAPTER XV

GENERAL CONSIDERATIONS

Frequency of head-wounds.—Wounds of the skull are common in the present war, as the head is often the only part exposed by men who take the best cover possible, but are obliged to keep an occasional look-out. These wounds are caused by projectiles often travelling at enormous speeds, are sometimes accompanied by a widespread damage, and are often immediately fatal.

Among those who survive, many are hit in the silent areas of the brain, and show few symptoms when the phenomena of shock have disappeared. Others, on the contrary, are struck in the essential functional areas, and often remain permanent invalids, even when they have escaped the various complications which are liable to carry them off.

In view of the frequency of wounds of the skull, everything possible should be done to diminish their number and gravity.

From the beginning of the war the men attempted to protect their heads from the showers of shrapnel with their trenching tool or a pot. Since the adoption of the trench-helmet the number of head-wounds has certainly decreased. The helmet often stops partially spent bullets or shrapnel, it always diminishes the velocity and lessens the penetrating power of missiles,

and it does away with the presence of fragments of the cap in the wound, which is a great source of infection.

The men must cut the hair very short in order to avoid contamination of the wound with long hairs, and to facilitate the shaving and cleansing of the scalp if it becomes wounded. The preparation of the field of operation should be carried out most carefully and as early as possible. It should be done at the aid-post, as it is of the greatest value. A wound in a dirty scalp, covered with long hair and filth, will certainly become infected secondarily, even if it is not infected from the first. Proust, who has been at the front since the beginning of the war, and has therefore been able to make a number of useful observations, attaches the greatest importance to this early toilet of the wounded area. The head should be gone over with the clippers, working always from the wound outwards so as to carry the clippings as far away from it as possible; it is then washed with soap and shaved, and afterwards treated with ether, alcohol, and with double-strength tincture of iodine. Finally a dry dressing should be most carefully applied so as to avoid any fresh contamination during the transport of the patient.

Transport of the wounded.—The wounded man should be transported as gently as possible to where he can be operated upon and admitted to hospital. As I shall explain later, the necessity for operation in head-wounds is generally not urgent, and those who consider it necessary to operate on a skull as one would operate on an abdomen are, I think, mistaken. If the abdomen, like the skull, contained only solid organs instead of containing hollow ones full of septic material, both might be treated alike. The only imperatively urgent surgery is that of the digestive tract and the circulatory apparatus. In-

juries of the bowels or heart or important vessels would justify the presence of ambulances and surgeons not ten miles, but half a mile from the firing line. Men with wounds of the brain will all gain by being transferred directly to a hospital where they can be installed once for all and remain for many months, provided always that the transfer does not mean a journey to a long distance during which the patient does not receive the necessary care and attention. This applies especially to men with wounds of the brain; in them it is important that the surgeon who performs the operation should follow up the case for a long time. If this had always been the practice, many surgeons who say that military cranial surgery yields comparatively good results would form an exactly contrary opinion. If they had followed their cases they would have seen that many of their patients who had, to all appearance, been cured for some weeks, subsequently died. It is only necessary to read the report of the medical conference of the 4th Army on the 18th June 1915 (*Presse médicale*, 1st July 1915) to be convinced of what I say, and it does not appear that very early operations performed at the front have, under the circumstances, been very successful, nor protected the patients from later complications.

Varieties of head-wounds.—Wounds of the skull by projectiles may be classified as follows:—

1. *Tangential wounds* in which the missile has grazed the skull, leaving a mere depression in the bone; sometimes, however, the internal table is broken into numerous fragments and the dura mater is injured. With these wounds may be classed those in which an almost spent missile has struck the skull and produced a depression of the external table, with, perhaps, a corresponding fracture of the internal table.

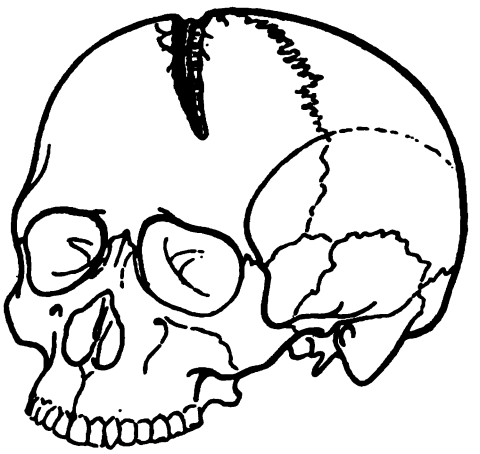


FIG. 1.—The projectile, generally a bullet, has followed a course tangential to the skull and has made a furrow in its thickness. The internal table is probably broken. This wound is the type of those which must be treated with the gouge-forceps. They often do very well.

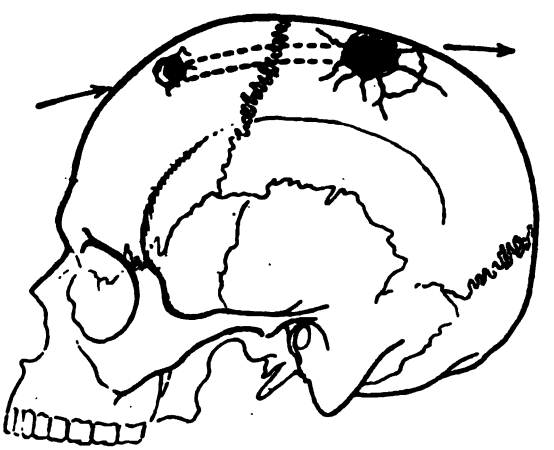


FIG. 2.—The projectile has penetrated the skull and passed out again, almost immediately, following the arc of a small circle. In these cases the brain and the dura mater are necessarily injured over a large area, but the cerebral lesions are not very deep, and the detached fragments of bone are never projected very far into the interior of the brain. These wounds are often cured if well treated.

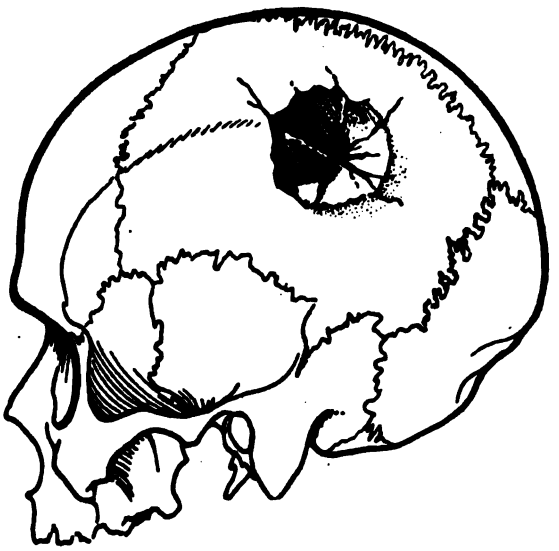


FIG. 3.—Here the projectile has struck the skull at right angles without penetrating it; both tables are broken, and the splinters of the internal table have probably been driven very far into the interior of the brain not far from the ventricle. These wounds, which are not very shattering, are amongst the most serious. This wound may be treated by a large osteoplastic flap.

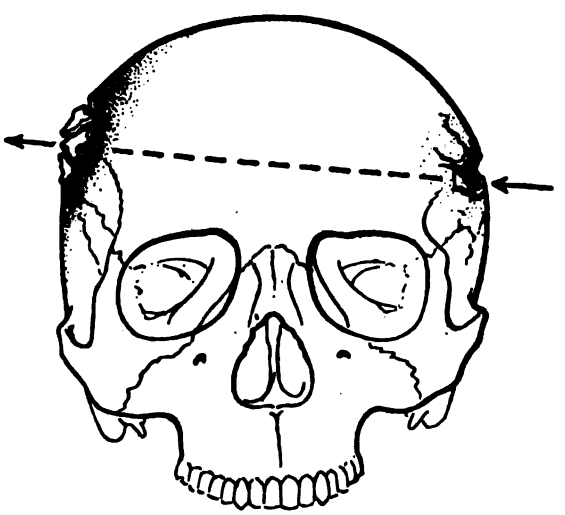


FIG. 4. –The skull has been traversed from side to side. On the side of the orifice of exit there are no cerebral splinters, these having been projected outwards. The orifice of entry is often small. These wounds, if they are not fatal at once, often do well.

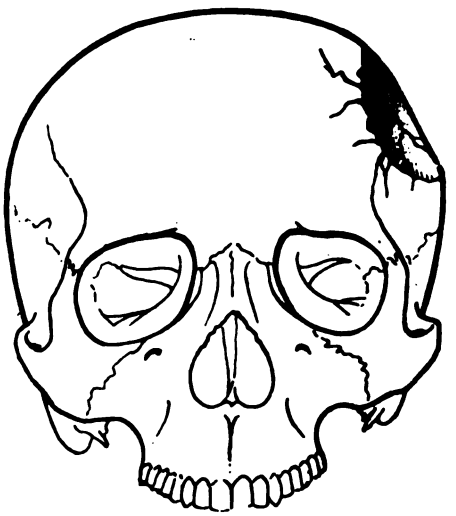


FIG. 5.—The skull has been driven in by a piece of shell of low velocity, and resembles the large injuries of civil practice. It is not uncommon to have to treat such fractures after the wrecking of shelters or explosions of mines.

FIG. 6.—In this case the skull and brain had been ploughed up by a shell-fragment for a long distance and to a great depth. There was blindness due to lesion of both occipital lobes. He finally died of meningo-encephalitis.

2. *Wounds in which the missile has penetrated the skull and passed out again* almost immediately, describing an arc of a small circle. In these wounds the brain and the dura mater are necessarily injured over a fairly large surface, but the cerebral lesions are not very deep, and the detached fragments of bone are never driven very far into the interior of the brain.

3. *Non-penetrating wounds.*—In these cases both tables of the skull are broken, and the fragments of the internal table are often driven very deep into the brain not far from the ventricle, which, even if it is not opened at once, may be injured in the course of the operation. These cases are particularly serious.

4. *Penetrating wounds.*—This type is identical with the previous one, except that in this the projectile has penetrated the skull, and then often lies at a deeper level than the splinters which it has driven in.

5. *Perforating wounds.*—These are cases in which the skull is traversed from side to side by a bullet. The orifice of entry is generally small, and the splinters are also small. If death is not immediate, these wounds often do well without operation.

6. *Cases in which the skull is driven in* by a large missile, such as the base of a shell travelling at a low velocity; they are marked by fractures of the skull resembling those seen in civil practice.

7. *Cases in which the skull and brain are ploughed up* widely and deeply by a large piece of a shell which cuts a broad longitudinal or transverse fissure.

This classification is only a rough one. Numbers have multiple wounds of the head of varying gravity and aspect, and others have wounds in other parts of the body which give rise to fresh difficulties in the treatment of the wound of the skull. The treatment will differ according to the variety of the wound.

It will be evident that the same methods of operation cannot be applied to a broad superficial wound of the skull and brain by a shell-fragment as to a deep and narrow penetrating bullet-wound. In the following pages I shall point out the procedure which appears to be most applicable to each particular case.

Importance of a careful examination before operation.—This is the only means of estimating the gravity of a case and of its subsequent improvement.

A patient with a head-wound must always be carefully examined. When the patient is comatose this can be done very rapidly, but in other cases it must be carried out most minutely. For this examination the reader should refer to Part I. of this volume written by Dr Chatelin.

It is obviously of interest to distinguish the phenomena due to shock, which disappear spontaneously more or less quickly if the patient does not die, from those connected with increase of intra-cranial tension, which continue to increase after receipt of the injury. These latter symptoms are improved by trephining, but a similar result can be attained equally well by lumbar puncture. Further on we shall see that one ought not to try to reduce the intra-cranial pressure in the early stages, for the increase of pressure luckily opposes extension of the meningitic phenomena that always exist at the level of injury when the wound is a penetrating one. It is also of interest to ascertain, by examining for motor, sensitive, and sensory troubles, to what extent the cerebrum and the cerebellum have been injured, and to what extent a complete cure of the patient may be hoped for. This examination is unfortunately seldom carried out because of its difficulty and length, which make it almost impossible when there is a great rush of wounded. When it can be carried out, it allows the

surgeon: first, to form an opinion as to the extent of the cerebral lesions, although the bulk of the symptoms may disappear and may be due merely to concussion and cerebral œdema; second, to make out how far the patient's condition is ameliorated

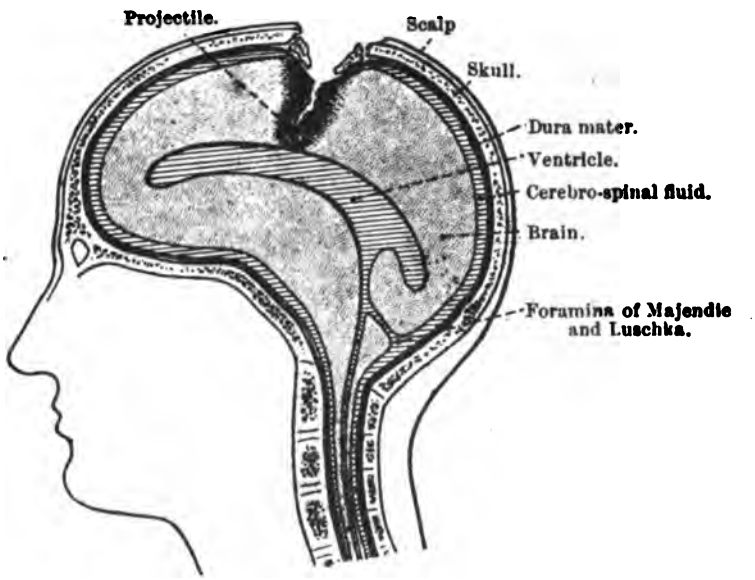


FIG. 7.—This diagram shows that the meninges and the brain adhere around the area of injury, and that this adhesion shuts off the general meningeal cavity. The projectile is seen very near the ventricular cavity, and it can be understood that incautious handling would open a septic focus into that cavity; provoking a rapidly fatal central meningitis.

or aggravated after the operation, and to draw from it inferences which may be useful.

An outline of the anatomy of the skull and its contents from which deductions may be drawn that will prevent the surgeon from adopting unsuitable measures.

The skull, the brain, and its dura matral covering (which is the only one of the meninges that really

matters from a surgical point of view) can be roughly represented as follows :—

1. The skull is a rigid shell continuous with the vertebral canal and formed of two laminæ, the outer and more tenacious called the external table, and the inner and more fragile called the internal or vitreous table.

2. The brain is a hollow vesicle with a very thick wall continuous with the spinal cord, which is likewise hollow. The irregular cavity in the brain forms the ventricles, the cavity in the spinal cord the central canal of the cord. Three orifices, the two foramina of Luschka and the foramen of Majendie, put the ventricular cavities into communication with the external surface of the brain. It must be remembered that this is merely diagrammatic, but the communication of the ventricular cavities with the sub-arachnoid space is sufficiently proved by the fact that in intra-ventricular hæmorrhages lumbar puncture draws off a blood-stained fluid.

3. The dura mater of the brain, which is continuous with the spinal dura mater, forms a fibrous bag, which lines the skull and the vertebral column without adhering to them.

The brain and spinal cord are in the interior of this fibrous sac, which is filled with the cerebro-spinal fluid, and the latter penetrates to the interior of the ventricles and the central canal of the cord by the foramina of Luschka and Majendie.

(No mention has purposely been made of the arachnoid and its two layers, nor of the supra- and sub-arachnoid spaces, which would only complicate the description without making the following explanations any clearer, for everything goes on as if that very fragile membrane, the arachnoid, did not exist.)

Let us now, with the help of this outline, study the

progress of an infection following an injury of the head and involving the skull, the meninges, and the brain.

After the injury the edges of the infected wound in the dura mater apply themselves to the brain and adhere to it. During the next few hours cerebral œdema is produced in the damaged area, and the swollen brain applies itself more and more firmly to the dura mater, and sometimes even herniates outwardly. Owing to these adhesions the damaged area is isolated from the meningeal cavity, and there is meningo-encephalitis localised to the region of the wound.

This infection may remain localised, but it may also spread gradually, invade the entire sub-dural space, and, through the foramina of Luschka and Majendie, the interior of the ventricles. In the latter case there is generalised meningitis, and the patient quickly succumbs. It is evident that the first thing to be done in order to avoid this fatal development is not to interfere with the existing adhesions between the dura mater and the brain. Any procedure which would lead to the rupture of these adhesions is deplorable. For this reason it is better, during the early stages of the case, to avoid introducing the jaws of large forceps between the skull and the dura mater, and causing pressure on the brain and meninges. For the same reason it is better during the same stage of the case not to practise lumbar puncture; this operation, by withdrawing a certain quantity of the cerebro-spinal fluid from the sub-dural space, causes a diminution of pressure in the ventricles, since all these cavities communicate freely with each other. Consequently there results a diminution of the swelling of the brain; it loses its exact application to the deep aspect of the dura mater, and it is on this close application of the brain to the dura that the limitation of the infection to the damaged area to a great extent depends.

When a projectile penetrates the brain it is situated near the ventricular cavity; around it there is always

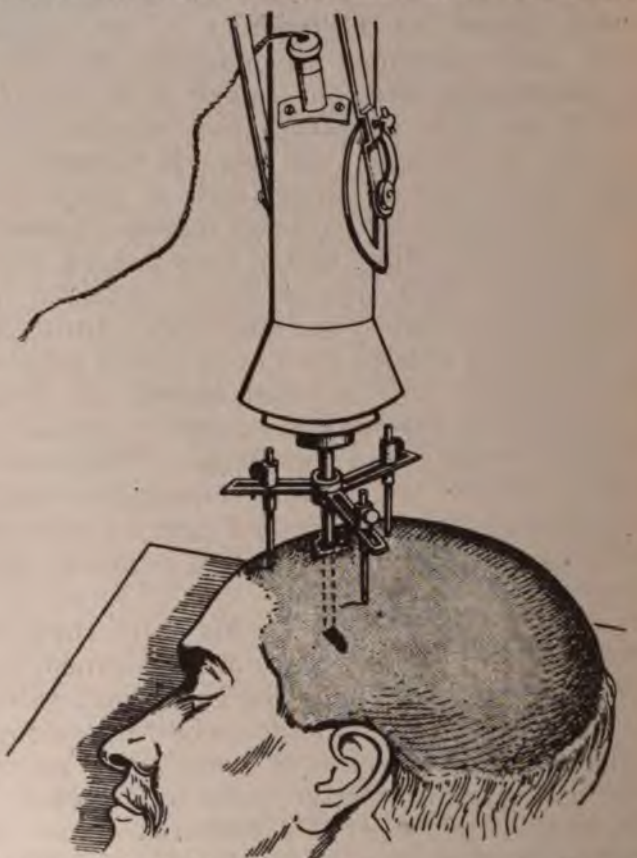


FIG. 8.—Sketch of Martel and Mondain's apparatus for the extraction of metallic foreign bodies. This modified Hirtz compass is made entirely of copper except the localising probe, which becomes the withdrawal rod, and is in soft iron.

a zone of infected tissue, and an abscess often forms. When extraction of the missile is taken in hand, there is great danger that the ventricular cavity may be opened and infected.

These elementary considerations are by no means

valueless, for, judging from the publications, the majority of surgeons seem not to heed them. The extreme urgency of cerebral operation, which is accepted almost as a dogma, is by no means proved. Intervention in a penetrating wound of the skull immediately after the injury as it generally is practised can only aggravate the infection by disseminating it. Indeed, the general practice is to enlarge the orifice of entry with a gouge-forceps. This clumsy instrument exercises repeated pressure on the brain and the dura mater, thus forcing into the sub-dural space the septic products contained in the damaged area limited by the adhesions. In what way does removal of a large area of the bone around the fracture, even if it be infected, benefit the patient? Men wounded in this way never die of osteomyelitis of the skull; that is not the danger. The immediate danger is almost exclusively meningitis, and the natural defences of the wounded man are much more effective against meningitis than the illusory help of surgery.

The surgeon must make up his mind that, as far as the brain and the meninges are concerned, he can do nothing, or next to nothing, against infection. The most that he can do is to do no harm, by exercising his prudence and lightness of hand so as to respect scrupulously the protective adhesions which have formed at the periphery of the traumatic area. In the case of the brain he should be satisfied with facilitating by judicious drainage the elimination of all the dead material the presence of which in the middle of the healthy brain substance facilitates, provokes, and encourages infection, and this should be done only if the situation of the wound allows of it. This, in my opinion, should be the limit of the surgeon's action. Should there be a systematic search for metallic foreign bodies, which are the only ones shown with

certainty by radiography? I do not think so, and yet this systematic and immediate search for foreign bodies is a dogma with many operators. Let it be borne in mind that the projectile up to the time of its arriving in contact with the tissues is aseptic, and has, a few seconds before, been raised to a temperature of several hundred degrees; in passing through the head gear, the hair, and the scalp it gets contaminated, but more than that, it draws behind it septic débris which will be the most active cause of infection, but which a radiograph will not show, and which there will never be any question of removing. Under these conditions there is no object in damaging the tissues anew as long as any encephalitis exists, and metallic foreign bodies should only be extracted when this can be done by a method which is precise in the extreme, clean, free from hesitation, and without any rocking of instruments, or pushing backwards and forwards in the brain substance. The foreign body is often not far from the ventricular cavity, which is sometimes separated from the operation area only by a thin layer of brain substance.

I shall return to this subject soon, but I may say here that my preference is, *a priori*, for extraction by an electro-magnet whenever this is possible—that is to say, whenever we have not to deal with shrapnel. With a powerful electro-magnet acting upon slender rods of soft iron which are introduced into the track of the projectile it is only necessary to approach within a short distance of this to pick it up, as it were, without any extraneous manipulation, which, as I have pointed out above, is of the greatest importance. With the collaboration of my friend, Dr Mondain, I have endeavoured to devise a very simple apparatus based on this principle. The localising apparatus is made entirely of copper, except the seeker, which is of soft iron. After trephining, this seeker is pushed

into contact with the missile and then magnetised by means of a powerful electro-magnet, which draws out both the seeker and the missile without any probing about.[1]

[1] By means of experiments on splinters of shell enclosed in a transparent medium of a consistency nearly identical with that of the brain we have found that the magnetised rod does not always draw out the metallic splinter at the first attempt, but that the attempt must be repeated several times. Under such conditions we shall use this arrangement under the control of radioscopy, which will enable us to re-establish the contact with all desirable gentleness as often as may be necessary.

CHAPTER XVI

TREATMENT OF A PATIENT WITH A WOUND OF THE SKULL

HAVING laid down these general principles, I can now proceed to the surgical treatment of wounds of the skull.

The hair is cut all over the head with clippers, always starting from the wound when possible, in order to carry the cut hairs away from it. I once more repeat here what I have said above, namely, that it is to be regretted that men are allowed to wear their hair long. This undoubtedly aggravates wounds of the skull, and sometimes makes the preparation of the field of operation very difficult. The scalp must next be shaved over the whole extent of the field of operation, and freed from grease with ether, and finally washed with alcohol, and painted with iodine.

Anæsthesia.—The question of anæsthesia in cerebral surgery is of the greatest importance, and it is surprising to see how little attention is paid to it by surgeons. The question has hardly been raised in any of the discussions on cerebral war-wounds that have taken place in the last two years. It should be the surgeon's aim to disturb as little as possible the relations of the dura mater and the brain in the injured area. He should especially avoid all to-and-

fro movements, and any movements that alternately bring together and separate the dura mater and the brain, as these may rupture the adhesions existing between these two structures. Under general anæsthesia it is very difficult to avoid alterations in the volume of the brain. Coughing and vomiting cause a sudden increase in the intra-cranial venous pressure, and a great tendency for the brain to become herniated. The result is that the whole of the damaged area is shaken up, the brain substance, which is very friable when its surface is cut, is damaged beyond the limits of the wound, the hæmorrhage is increased, and the adhesions of the brain to the dura mater are interfered with. In addition, vomiting often lasts for several days after the operation, and this always exposes the patient to the same risks, which are sometimes very serious.

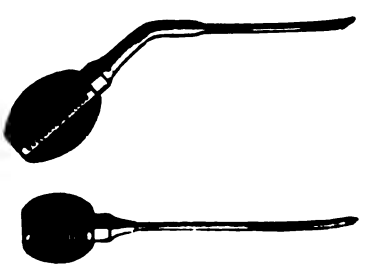
General anæsthesia also necessitates the horizontal position, which greatly exaggerates the venous bleeding in all head operations, as the veins are without valves. This is often of little consequence; but if the surgeon unexpectedly finds himself confronted with a free opening into a sinus, for instance, he meets with difficulties which would not have arisen if the patient had been seated.

Finally, under general anæsthesia the patient cannot be of any assistance to the operator. Under local anæsthesia, on the other hand, the patient can shift or alter his position, and especially he can inspire and expire deeply, which, as we shall see, may be very helpful in the conduct of the operation, particularly in diminishing a venous hæmorrhage (inspiration) or in everting the lips of a cerebral wound (expiration).

TECHNIQUE OF LOCAL ANÆSTHESIA IN OPERATIONS ON THE SKULL.—For more than three years I have performed all serious cerebral and cerebellar operations

under local anæsthesia. I make use of the simple technique which MM. Pauchet and Sourdat endeavoured to popularise in their excellent work in 1914.

The scalp and the skull derive their sensibility from nerves which travel under the skin and the epicranium. They are very easy to reach, and it is easy to infiltrate the tissues which they traverse by following a line which encloses the future field of operation. All the tissues, the skin, epicranium, periosteum, and bone thus enclosed rapidly become insensitive. The dura mater is



FIGS. 9 and 10.—Syringe with wings allowing of great pressure being put on the piston. Straight and elbowed needles.

almost devoid of sensibility, and can be pinched or cut without causing any pain, except near the base of the skull in the temporal region.

Syringes.—The syringes should hold 5 or 10 c.c., and there should be several. They must be perfectly air-tight, provided with a metallic top furnished with finger wings, which enable a strong pressure to be put on the piston.

Needles.—The needles may be of platinum or steel.

Platinum needles have the advantage of not wearing out, but they soon get blunt, and are very expensive. Steel needles are quickly worn out, and whatever care may be taken of them, they must be often replaced. Nevertheless I prefer them. There should be several of various diameters and lengths, 2, 3, and 4 inches. They should fit the syringes accurately, otherwise there will be considerable loss of the injection fluid, and it will be impossible to tell exactly how much has been injected.

To sterilise the needles and syringes it is sufficient to immerse them in alcohol at 90° C. They should then be rinsed in sterile water just before use. The needles, syringes, and the capsules of novocaine solution should never be boiled in water containing carbonate of soda, as is the custom with most instruments, as novocaine is precipitated by carbonate of soda, and the solution loses all its anæsthetising action.

The anæsthetising solution.—I use a solution of novocaine-adrenalin containing 1 gramme of novocaine and 1 milligramme of adrenalin to 200 c.c. of physiological (artificial) serum. In some very extensive operations I have injected as much as 100 c.c. of this solution without the slightest inconvenience, and in some abdominal operations I have gone up to 200 c.c. without accident, which shows the harmlessness of this method.

Position of the patient.—If it be possible—and in cases most suited for operation it generally is possible—the patient is seated on a chair. The best way is to put him astride on the chair, with his arms supported on the back and his head leaning on his arms. In this way the lateral and posterior portions of the skull are easily exposed, and the patient can maintain this position for a very long time without fatigue. For an operation on the frontal region the

patient sits down and throws his head back and rests it on the edge of the operating table. With the co-operation of my friend, Dr Mondain, I have had a special chair made, which M. Malaquin has been so good as to construct.

Pretty often the patient has to be laid on the operating table, either because he is unconscious, or

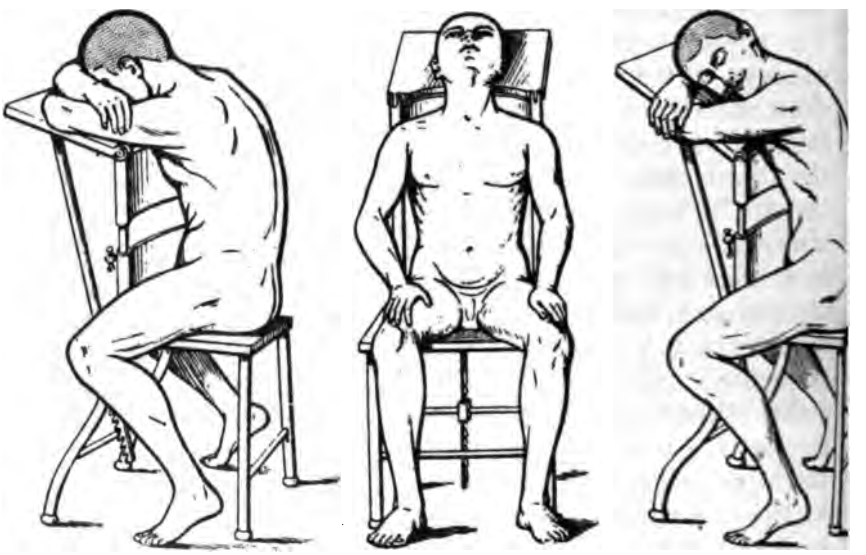


FIG. 11.—The patient is operated upon in the sitting position. From right to left are shown the positions to be taken for operations on the occipital, frontal, and parietal regions respectively.

because some other wound prevents his being seated. In such cases the head must be raised, which is easy with the tables generally used. The operator should then stand on something while operating, otherwise he is too low, and is obliged to operate with his elbows in the air, which is very inconvenient.

Before applying the anæsthetic the operator should satisfy himself as to the possibility of cutting an osteo-plastic flap, and also as to the proper size of the flap. It is possible to operate in this way when-

ever there is no considerable loss of bone, which is most frequently the case. In very large wounds with great loss of tissue, in which the skull has been widely opened, this method cannot be employed. I shall return to the subject later.

If the bony lesion is of some size the edge of the flap should pass an inch outside it in all directions, otherwise there would be a risk of coming down on splinters detached from the internal table during the section of the bone flap. When the size of the flap, which should always be quadrangular, has been decided upon, the four corners are marked by four intradermic injections of novocaine - adrenalin. To make these injections the needle is pushed into the thickness of the dermis parallel to its surface, taking care to avoid passing through it. When the injection is properly made, there is some difficulty in pushing home the piston of the syringe; this difficulty disappears as soon as the injection becomes subcutaneous.

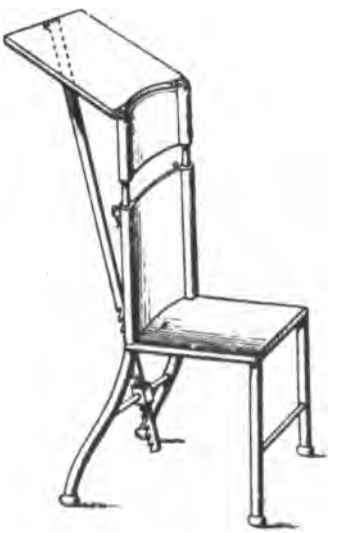


FIG. 12.—Special chair for trephining in the sitting position.

When the four injections have been made, the fine short needle which has been used is replaced by another 3½ inches long and of a larger calibre. With this subcutaneous injections are made all along the line of the future flap, or rather immediately outside it (see fig. 13). For this purpose the needle is pushed through the scalp at the corners of the flap, which have already been anæsthetised by the intradermic injections.

After a variable, but generally very short, time insensibility of the whole surface of the flap will be

FIG. 13.—Four intradermic injections are made at the four angles of the flap. It is at these four perfectly-anæsthetised points that the long needle with which the subcutaneous injections are made will be inserted.

obtained; this is easily ascertained by pinching its surface with a Kocher's forceps. One must not expect, however, that the patient will not complain

during the operation. A nervous and emotional patient will complain as soon as he suspects that he is being cut or pricked, but he really feels nothing. However, it is very easy to avoid causing the patient this apprehension of the pain which he does not feel, but which he is afraid of feeling, by giving him a whiff of chloroform every now and then; this does not fully anæsthetise him, but completely calms him. A subcutaneous injection of half a milligramme of scopolamine will answer the same purpose.

APPLICATION OF A HÆMOSTATIC SUTURE TO THE BASE OF THE FLAP.—It is very important to operate bloodlessly, especially as these patients are often very deeply shocked. Therefore before cutting the flap I underrun the whole thickness of the tissues of its base down to the bone with a stout silk suture, as shown in fig. 14. It will be seen that every artery is in this way enclosed by a loop of the suture. The cutaneous flap, when detached from its connections with the rest of the scalp, will be then entirely ischæmic, and will not bleed, and it will only be necessary to place forceps on the peripheral lip of the incision. These forceps fall away from the field of operation, lie lightly on the scalp, enlarge the cutaneous incision, and facilitate the later stages of the operation, without causing any inconvenience. It is only necessary to look at fig. 15 to see this. The formation of the quadrilateral flap is done in three stages by three successive rectilinear incisions.

To prevent any hæmorrhage, an assistant places the ulnar border of his hand on the scalp parallel to the future line of incision and presses vigorously. The surgeon does the same with the ulnar border of his left hand, and incises between his own hand and the assistant's. Then, without removing the hands, small T-shaped forceps of my own design, made by Collin, are placed in all along the edges of the incision.

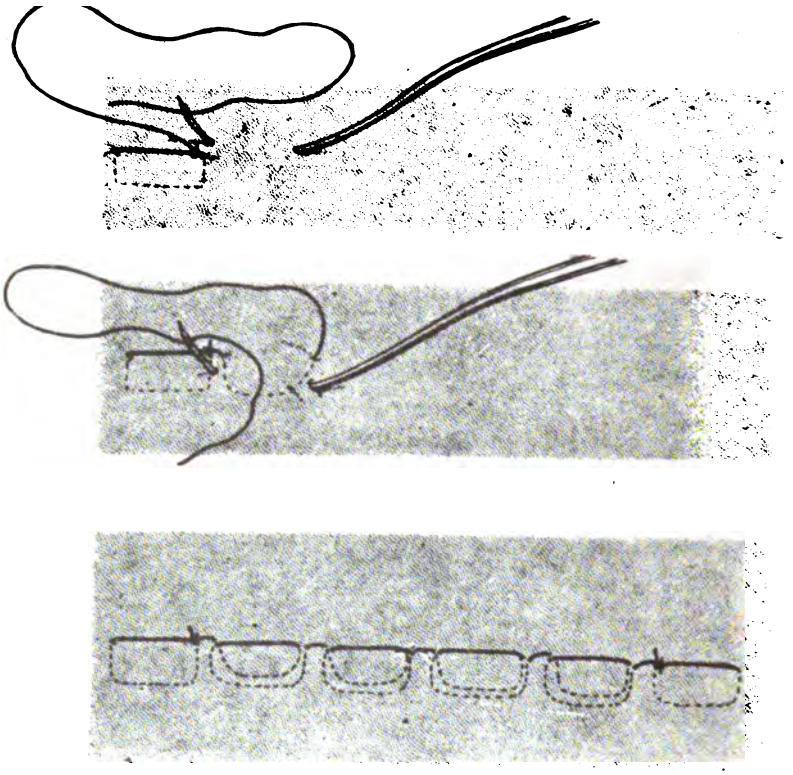


FIG. 14.—Method of inserting the hæmostatic suture, and diagram of the course of the thread.

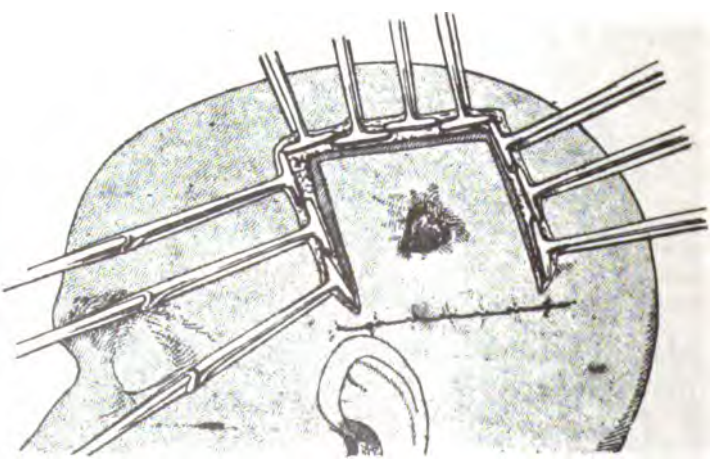


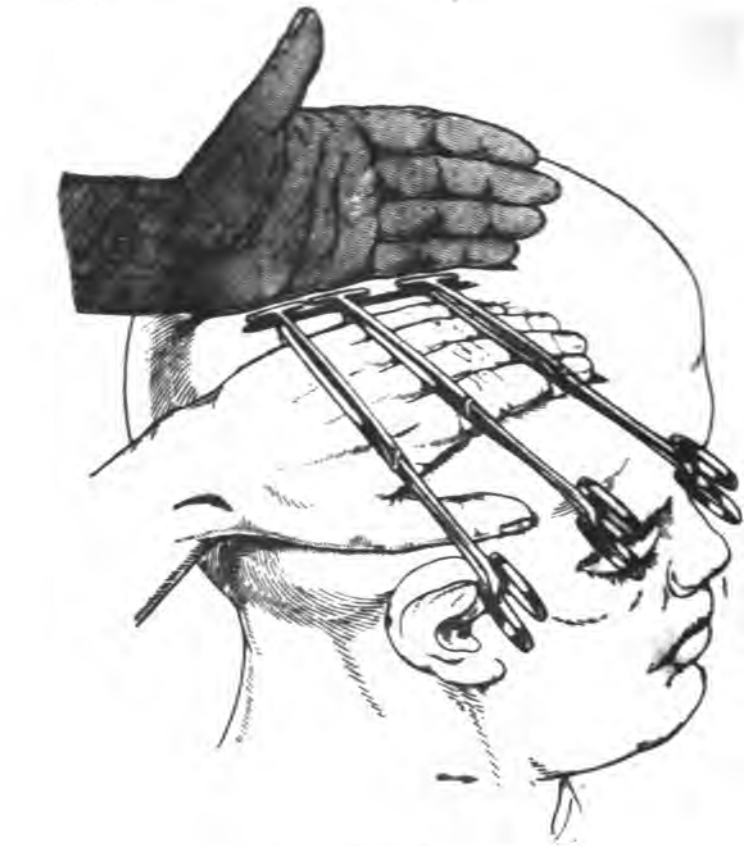
FIG. 15.—By means of the hæmostatic suture the scalp flap, once it is cut, will be entirely bloodless and will not bleed, and it will only be necessary to place forceps on the peripheral edges of the incision.

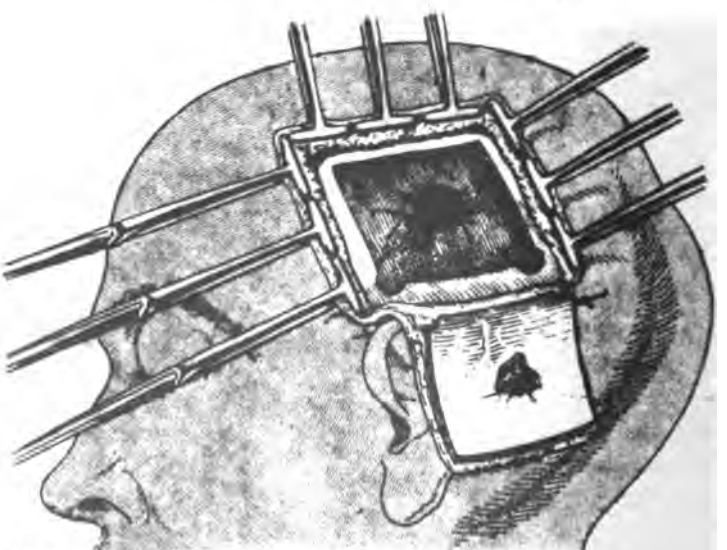
These forceps, shaped like a short T, and provided with small teeth, grip strongly, never slip, are easily applied, and exert a forci-pressure sufficient to make

FIG. 16.—To prevent any hæmorrhage the assistant presses the ulnar border of his hand firmly on the scalp. The surgeon does the same with his left hand laid flat, then incises between his hand and that of his assistant, and immediately puts on the T-forceps.

the bleeding after their removal absent or very slight. A similar manœuvre is repeated on the two other sides of the square flap, and when the flap has been thus completed the two lips of the incision are furnished with forceps, and not a drop of blood has been spilt.

At this time and during the rest of the operation





FIGS. 17 and 18.—View of the field of operation after turning back the temporary osteo-plastic flap.

the forceps on the internal lip of the incision would be very inconvenient, but as they no longer serve any useful purpose they can be removed. Indeed, the cutaneous flap can no longer receive any blood except through its base, but at this level all circula-

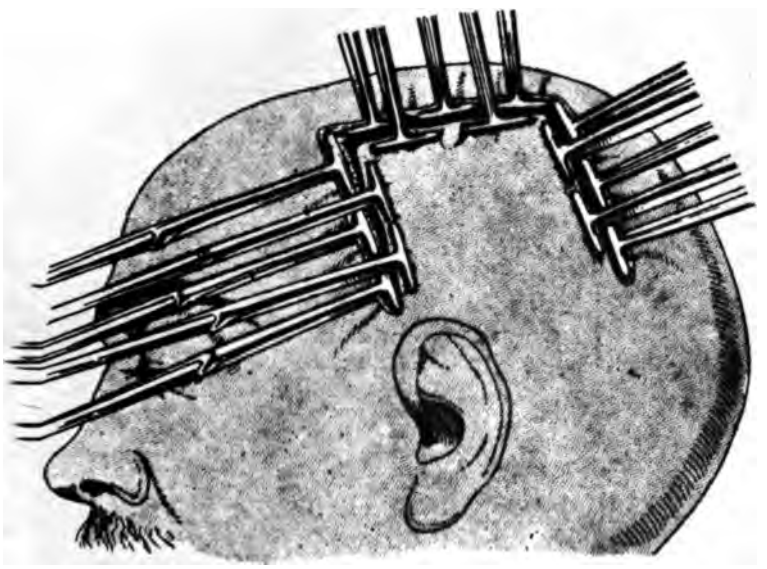


FIG. 19.—In this figure the forceps are well placed. Those of the peripheral lip evert the skin and uncover the bone. Those of the internal lip placed parallel to the preceding do not separate the scalp from the bone-flap, the nutrition of which it ensures. The figure shows that the operation would have to be performed in the middle of a crowd of forceps if the hæmostatic suture did not allow of the removal of the forceps on the flap.

tion in the vessels is intercepted by the suture placed there at the beginning of the operation. The field of operation now has the appearance shown in fig. 18, and once the forceps on the external lip of the incision have been turned out of the way, the operation area is perfectly clear. The removal of the forceps from the edge of the flap is a great advantage, because it is proposed to cut an osteo-plastic flap and not

to detach the scalp from the bone; the section of

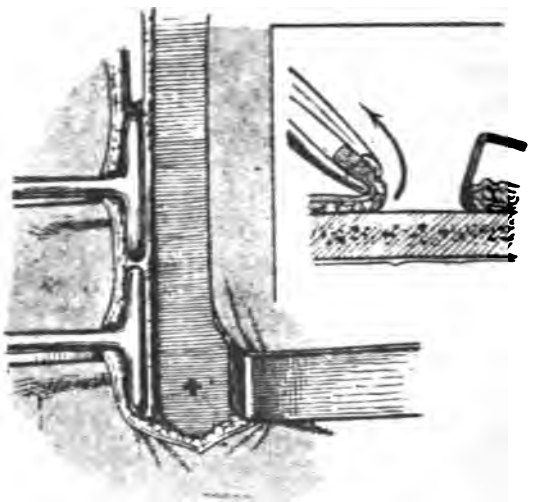


FIG. 20.—Care must be taken not to pull the cutaneous flap from the bone which it covers. This diagram shows how to proceed to uncover the bone at the point where the perforator is going to work without causing stripping of the flap.

the bone would otherwise have to be done between

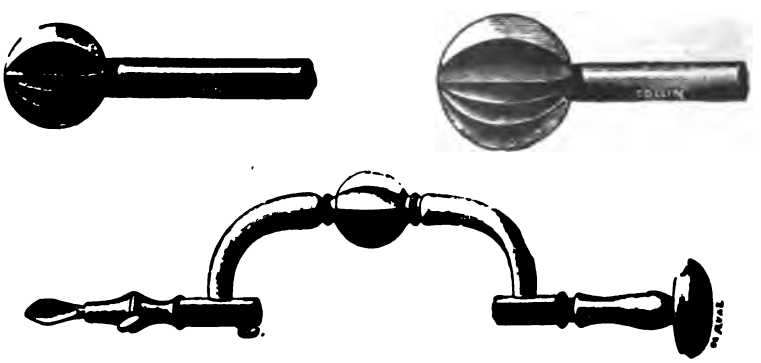


FIG. 21.—Doyen's perforating instruments.

two rows of forceps, and would thereby be rendered very laborious.

The use of rectilinear incisions for the cutaneous flap is justified on several grounds. The application of the T-forceps with rectilinear jaws is much easier on the edges of a rectilinear wound. At the end of the operation hæmostasis is merely by accurate

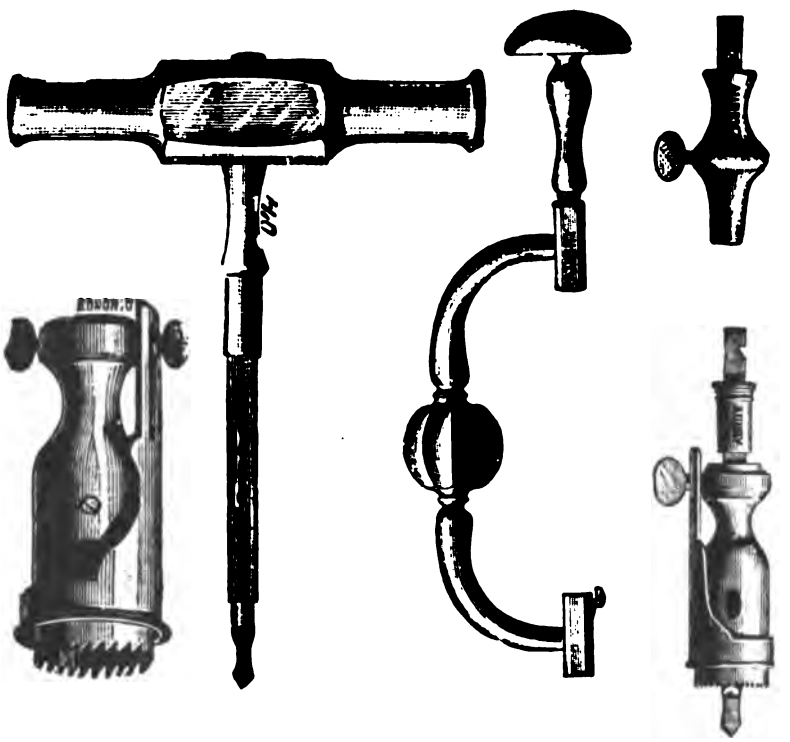


FIG. 22.—Crown trephine. These instruments are difficult to manage, but are strong and do not get out of order.

coaptation of the edges of the incision; this is much more easily done with a straight incision than a curved one, as there will often be puckering at the points where the edges are not brought perfectly together along the latter. When it is proposed to cut an osteo-cutaneous flap the greatest care must be taken not to reflect the scalp from the subjacent

bone, to which it is only loosely adherent. Therefore when placing the T-forceps on the inner lip of the incision (that of the flap), one should be careful not to throw the handles back towards the centre of the flap, and so evert the edge of it and bare the skull beneath to an undue extent. On the contrary, these forceps must be placed in a position similar to that of the forceps on the other lip of the wound, which can and must be everted in order to uncover enough of the bone to allow the drilling and cutting to be performed easily. The undue exposure of the edges of the osteo-plastic flap by pulling back the scalp has serious inconveniences; it may cause osteitis and necrosis in the edges, which leads to prolonged suppurations all along the incision. If the procedure is properly carried out, it is followed by sound healing in a few days.

When the flap has been marked out, and before dividing the bone along the same line, the edges of the scalp wound, which are generally lacerated, must be excised. This can be done without hæmorrhage in the centre of the ischæmic flap.

Section of the bone.—I cannot describe here the section of the bone in full detail. Personally, I always use my own mechanical apparatus, which enables an osteo-plastic flap of any shape to be cut in a few minutes. But as this volume is intended for surgeons who have only the regulation instruments supplied by the medical service—a circular or a Doyen's trephine, Gigli's saw, and Marion's protector or my dura mater separator—it is only operations performed with these instruments that will be described at first.

CHAPTER XVII

TRUE CRANIECTOMY

Section of the Bone

A CRANIECTOMY is not satisfactory unless it is done quickly, without unduly shaking the patient's head, and without damaging the brain, or even the dura mater. To avoid shocks to the subject's head the use of the mallet and chisel should be given up.

FIG. 23.—Marion's dura mater protector

To avoid wounding the dura mater, the best way is to divide the bone from within outwards, thus moving away from the danger zone instead of towards it. Gigli's saw allows one to open the skull in accordance with all these requirements.

For this purpose it is sufficient to make a small trephine hole at each corner of the polygon of bone it is proposed to remove, and then to saw through the bridges of bone bounded by these orifices.

In order to operate quickly by this method it is necessary to be able to pierce the skull rapidly and to pass the saw easily from one trephine hole to the other under the bridge of bone which is to be cut. In order that the sawing may be done safely it is necessary to protect the dura mater; the saw

stretched between the two orifices in the skull, represents the chord of the arc of bone bounded by these holes, and, in spite of the fact that the skull is only slightly concave and the holes a short distance apart, the Gigli's saw would otherwise penetrate the convex surface of the brain. Figs. 25 and 26 explain my meaning well.

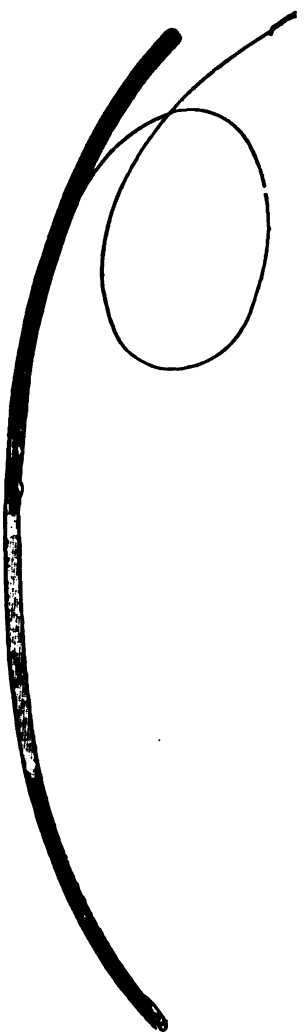


FIG. 24.—Martel's dura mater separator.

I shall now describe in succession the method of drilling the holes, of passing Gigli's saw, and of protecting the dura mater.

Opening the skull. — The method of opening the skull laid down in nearly all the classical works is bad. Marion points out the right method in his treatise without laying much stress on it.

As a rule, it is advised that the bone should be cautiously broached with the point of the perforator and then the brace and bit substituted for that dangerous instrument. But in order to perforate the skull rapidly it is necessary to drill the hole with the perforator right down to the dura mater, and then quickly to enlarge the bottom of the funnel thus formed with the brace and bit. These two

methods seem to be almost identical; but try them for yourself, and you will be able to judge.

It is evident that caution must be observed when approaching the dura mater, but it is very easy to

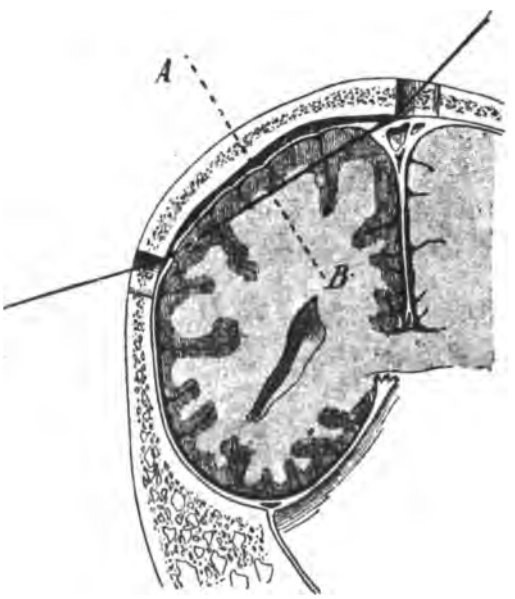


FIG. 25.—Gigli's saw is stretched between the two orifices which it traverses, representing the chord of the arc of bone bounded by these holes, and although the skull may be only slightly concave, and the holes only a short distance apart, the saw cuts into the convex surface of the brain.

follow the progress of the point. On cutting through the thick and resistant external table white chips of bone are detached, then the diploë is opened, and a blood-stained paste escapes which foams up round the instrument; when the internal table is traversed definite bone chips appear again, but this time they are reddened by the blood which continues to ooze from the diploë.

When it is proposed to cut a median symmetrical

osteo-plastic flap much time may be gained by proceeding as follows: A first hole is drilled cautiously but not slowly, and while doing so the operator counts the number of turns given to the instrument. In order to perforate the skull a second time very rapidly it

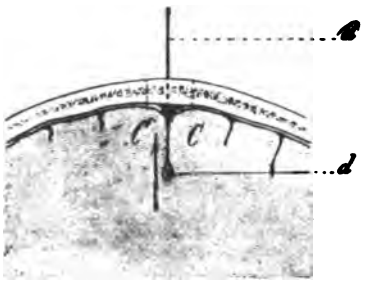


FIG. 26.—Gigli's saw is stretched between the two orifices which it traverses, representing the chord of the arc of bone bounded by these holes, and although the skull may be slightly concave and the holes only a short distance apart, the saw cuts into the convex surface of the brain.

will suffice to move the point of the perforator to the corresponding point on the opposite side, and to make the same number of turns at full speed. This method is the simplest if the operator does not possess my hand-perforator, with which it is possible to make a hole in the skull half an inch in diameter without taking any special precautions. Unfortunately Doyen's perforator and brace and bit require to be perfectly sharp before use. I believe that my hand-perforator is but little known, and that there are only a few specimens in existence, so one has often to be satisfied with the old circular trephine supplied by the medical service. This is a

FIG. 27. Martel's hand-perforator, with which it is possible to drill a hole in the skull half an inch in diameter without taking any precaution.

strong instrument which will always cut, even when it is badly kept.

Gigli's saw. Protection of the dura mater.—Marion's guide is used to pass Gigli's saw from one trephine hole to the other. This instrument consists of a band of malleable metal with a groove in it (fig. 28), and is supposed to be used as follows: It is pushed through one of the trephine holes and made to emerge from the other; then the saw is slid

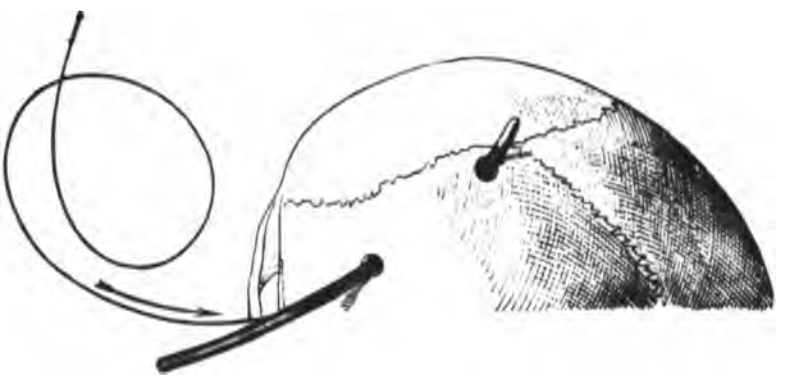


FIG. 28.—The protector has been pushed from one trephine hole to the other, and Gigli's saw is in course of introduction between the protector and the bone.

along the groove between it and the bone, and the bridge of bone is sawn through after withdrawing the guide (fig. 28). These are the instructions for use which Marion gives in his excellent treatise. But the guide may also serve as a protector, for which purpose it is left in place during the sawing. However, whether the guide serves as a protector or not, its passage from one trephine hole to the other is often very difficult. In fact, although it may be malleable it is rigid, and when an attempt is made to push it from one trephine hole to the other, it will be all right if the skull is not very thick and is only slightly convex, otherwise it raises a projection on

the dura mater, pushes up against it, and can only proceed by ploughing a furrow in the brain (fig. 29). Where there are bony ridges on the deep aspect of the skull (as in the occipital region, for instance) Marion's guide cannot pass over them with certainty.

While using this instrument I have ploughed a rather deep furrow on the surface of a brain. I have

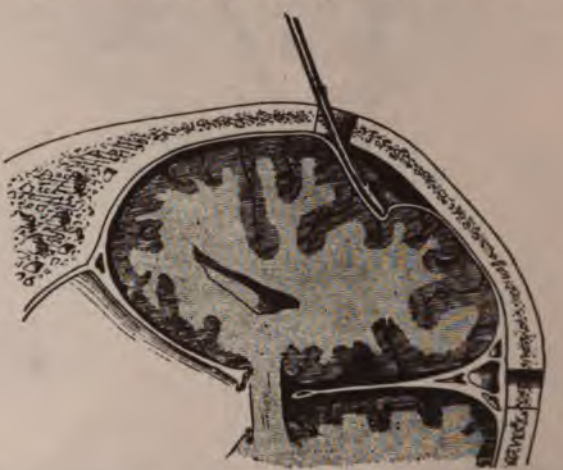
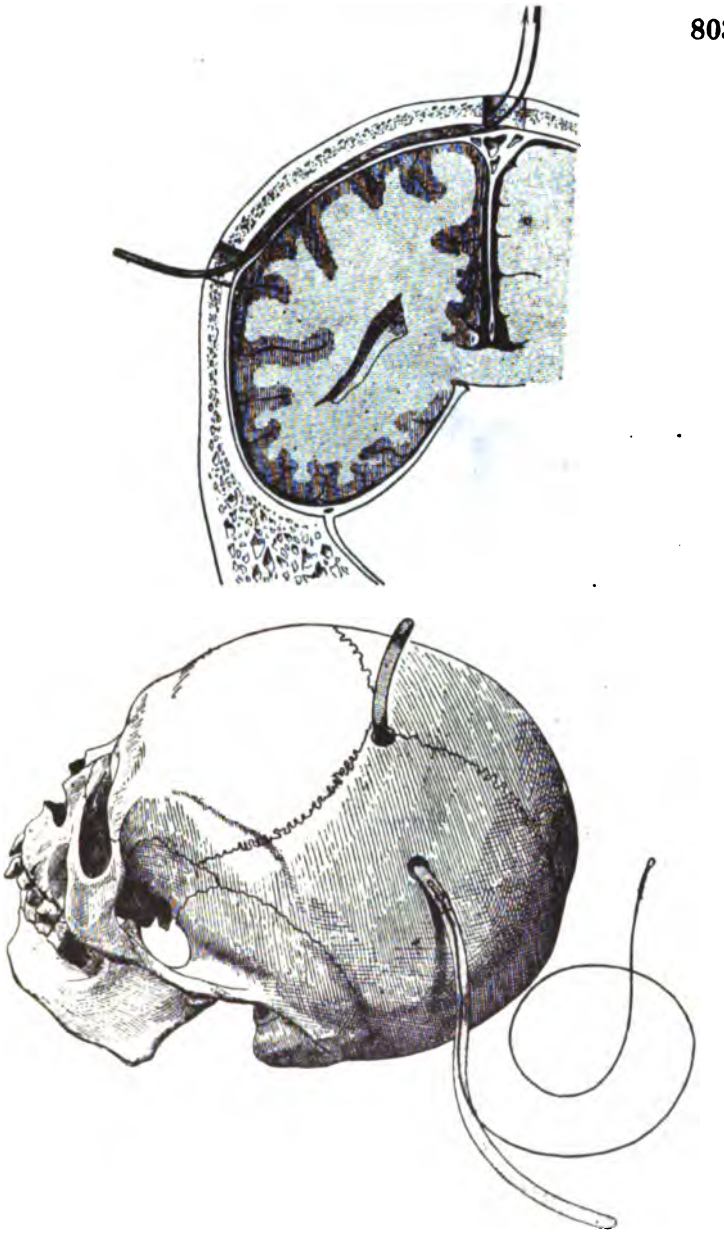


FIG. 29.—The cranium is thick, so Marion's protector is raising a f on the dura mater and the brain which it will plough up if a rou operator continues to push the instrument onwards.

seen two experienced operators (Professor Segond and Sergius Rabinovitch) do the same, and I know of surgeons who have been obliged to give up passing Gigli's saw by means of the guide.

It may happen sometimes that after getting the guide into position the saw cannot be made to slide along the gutter; this can be got over by attaching it to the end of the guide, which has a small hole for this purpose. When the guide is withdrawn the saw is drawn with it, but then the instrument serves simply as a tractor and no longer protects anything.

I have designed and got M. Collin to make a small



FIGS. 30 and 31.—As it penetrates, the slender steel ribbon, keeping its beak against the bone, fits itself exactly to the interval between the dura mater and the skull, and emerges as soon as it reaches the hole of exit.

tool, which was presented in my name to the Societe de Chirurgie by Professor Segond. I have since perfected it, but it still remains very simple (fig. 24). It is a simple steel band about 10 inches long and ½ inch broad, very thin, perfectly elastic, and highly tempered. The band is curved on the flat. One of its extremities, the beak, which is slightly rounded and thick, loosens the dura mater. Four inches from the beak, on the upper concave surface, there is a hook with its end turned down pointing to the beak. The instrument is passed through one of the trephine holes beak uppermost and pushed, without any precautions, between the dura mater and the bone towards the next opening. As it goes, the slender band of steel, scraping against the bone with its beak, fits exactly the space between the dura mater and the skull, and emerges as soon as it reaches the hole of exit (figs. 30 and 31). It is then only necessary to fasten the Gigli's saw on to the little hook of the instrument and to pull on the latter. When the saw has been pulled through, the posterior part of the dura mater separator remains in its place and acts

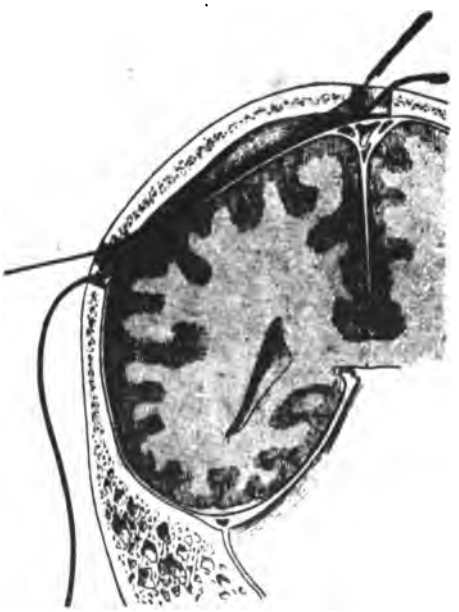


FIG. 32.—The saw having been passed through, the posterior portion of the dura mater separator remains in its place and acts as a protector.

as a protector (figs. 32 and 33). This instrument passes from one trephine hole to the other with the

FIG. 33.—See fig. 32.

greatest ease, however far apart they may be; it passes over any bony ridges without the slightest difficulty, draws after it the Gigli's saw, and separates it from the dura mater, which it protects efficiently.

Before designing this dura mater separator I had done craniectomies with the usual instruments, and

Fig. 34.—In this operation the dura mater separator has had, in order to pass from one to the other of the two lower trephine holes, to insinuate itself between the sinus and internal occipital crest, which is very projecting and quite visible in the figure.

Fig. 35.—This patient underwent total craniectomy ; it took thirty-five minutes to perform the operation.

also with Marion's guide and Gigli's saw, so that I am well able to judge of the difference.

All the first craniectomies which I performed with my instrument were difficult. They were cases of cerebral tumour in adult subjects with very hard and thick skulls; seven of the osteo-plastic flaps detached were median, and situated across large sinuses. In particular, I removed rapidly and at a single sitting the whole of the lower portion of the occipital bone up to within nearly ¼ inch of the occipital foramen, laying bare the cerebellum, the occipital lobes of the cerebrum, the torcular Herophili, the lateral sinuses, and the superior longitudinal sinus (fig. 84). I have even removed in thirty-five minutes the whole of the vault of the skull without any difficulty from a patient with a very thick and very hard skull who had extreme increase of intra-cranial pressure, which is seldom done except in the post-mortem room (fig. 85). All the patients operated in this way survived the operation; one of them died a month later, but the shock of the operation was not in the least to blame for this.

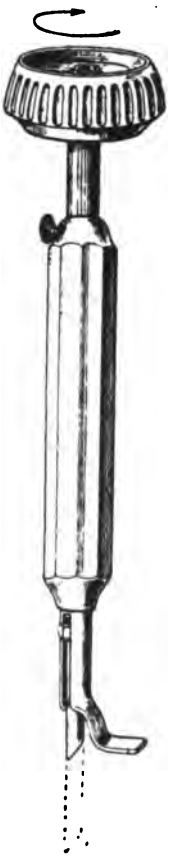


FIG. 36.—Martel's bone fracturer, which enables the base of the bone-flap to be broken without shock.

The operation, performed as I have just described it, is very simple on a normal skull; if the latter is fissured, there may be some difficulty. In this case my dura mater separator, while insinuating itself between the bone and the dura mater from one trephine

FIG. 37.—The bone fracturer is made in two parts, a male and a female portion, which slide on each other by means of a screw controlled by the handle at the top of the instrument. The female portion ends in a flat piece, which is insinuated under the bone-flap; the male piece is fined down to a point, which is supported on the skull just outside the flap. By turning the handle of the instrument the female piece is raised, and with it the flap, which is soon broken across its base.

hole to the other, may hitch against a projection from a fissure; should it do so, it is better not to force it, but to cut a new trephine hole at this

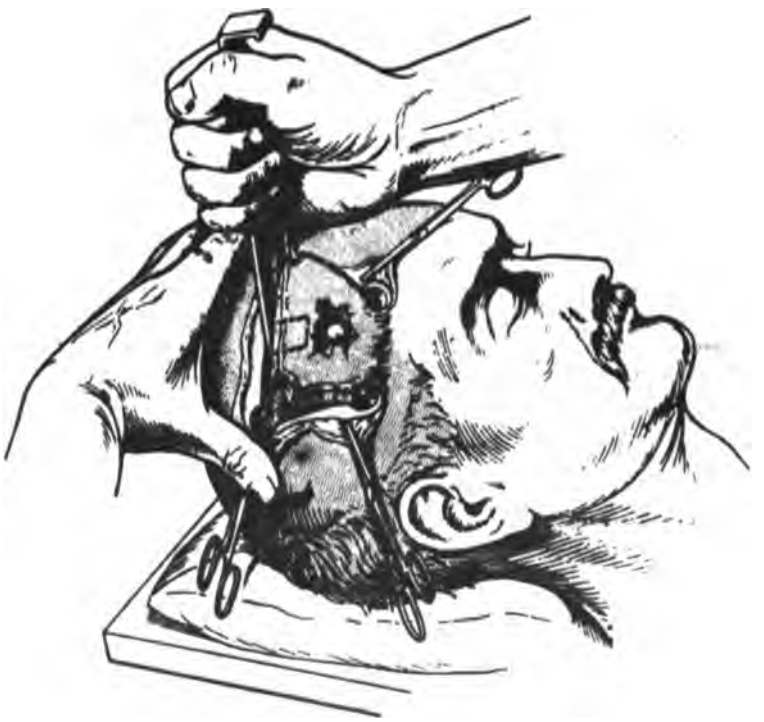


FIG. 38.—Fracture of the base of a bone-flap by traction with a Farabeuf's retractor. This rough procedure is very badly borne by a patient who is conscious.

spot. Or it may happen that the dura mater separator gets entangled in a laceration of the dura mater. This is very exceptional, but the obstacle can generally be got over by passing the instrument in the reverse direction.

When the section of the bone has been accomplished, it only remains to fracture the base of the bone-flap, which ought to be perceptibly narrower than its upper

edge; in other words, the flap should be shaped like a trapezium with its small side downwards. To effect this fracture without shock I use a very simple instrument, which I designed and had made by

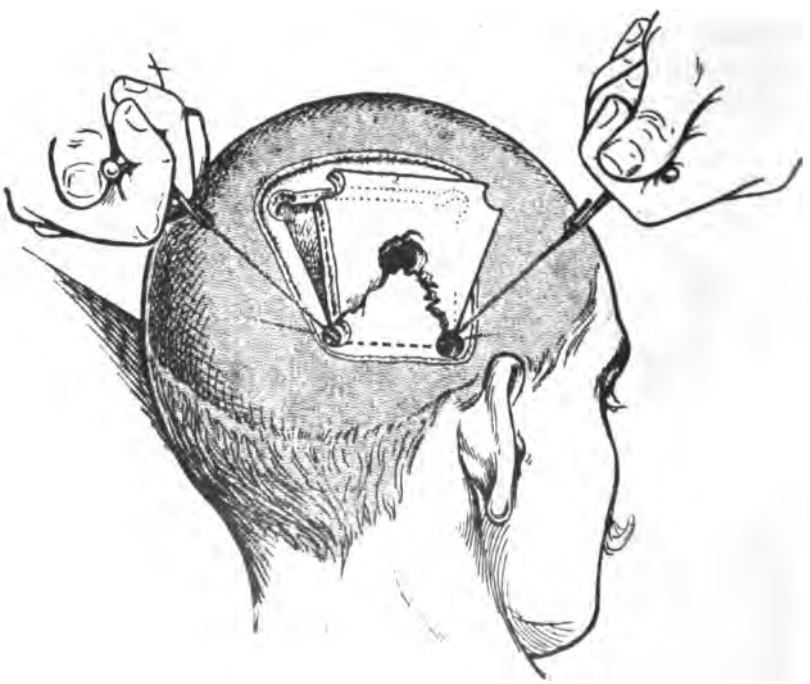


FIG. 39.—The flap is deeply fissured, and is not broken at its base. It is then necessary to cut with Gigli's saw what could not be broken. This figure is purposely incorrect; the flap should be covered by the scalp.

M. Collin (fig. 36). It is in two parts, a male and a female portion, which slide on each other by means of a screw worked by the handle at the top of the instrument. The female portion ends in a flat piece, which is passed beneath the upper edge of the flap; the male piece ends in a point, which rests on the

skull just above the flap. By turning the handle of the instrument the female piece is raised and with it the flap, which soon breaks at its base. This breaking of the base of the flap without a shock is important to a wounded man who is not insensible. In default of the instrument which I have just described, and which is not yet on sale, as it had only just been finished when the war broke out, Farabeuf's retractor may be used. The end of the large arm of

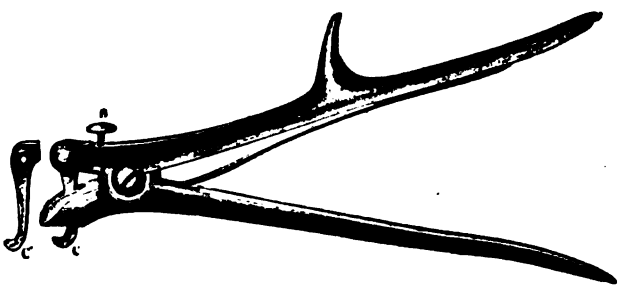


FIG. 40.—Dalgren's forceps, which require considerable force in handling.

this is introduced beneath the flap, while the heel, resting on the skull, serves as a fulcrum to the lever thus formed. Unfortunately the elevation of the flap obtained in this way is not very great, and is often insufficient to fracture the base. It is then necessary to pull on the retractor without supporting it on anything, and at the moment of fracture the wounded man experiences a violent shock (fig. 38).

If the flap is extensively fissured it may break into several pieces, or at some other point than the base (fig. 39). This accident is annoying, but it can be completely remedied. It is only necessary to pass the dura mater separator under the base of the flap, pushing back the scalp sufficiently to avoid cutting it with the Gigli's saw, which will sometimes

make it necessary to prolong the incisions downwards; the base of the bone-flap is then partially divided so as greatly to facilitate the fracture. In practice this accident should very seldom happen, because this method is only used in cases where the skull,

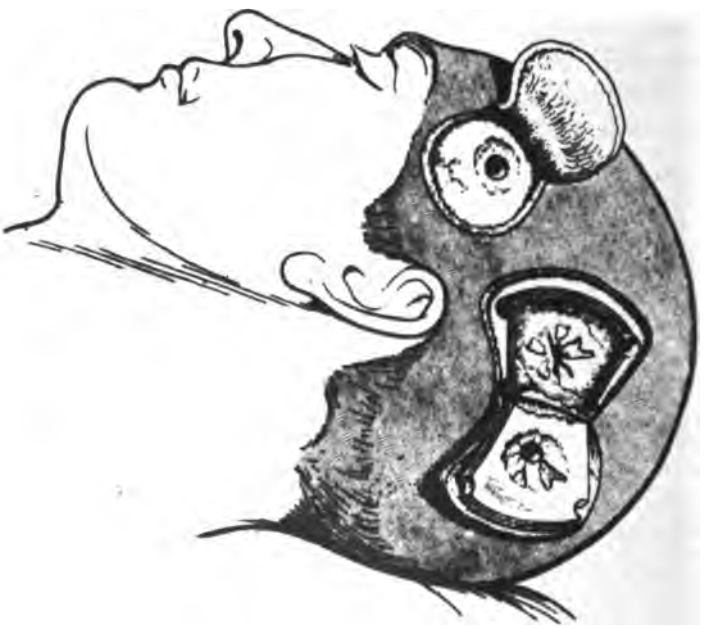


FIG. 41.—When the osteo-plastic flap has been raised the operator can see the lesions of the internal table and of the dura mater.

although perforated, appears to be strong and has no long fissures on the external table. It will be evident that when the skull is shattered there will be no idea of cutting an osteo-plastic flap.

Instead of Gigli's saw, Dalgren's forceps may be used to cut the bone (fig. 40). The great drawback of this instrument is, that it requires the use of considerable force. In any case it cannot be used to divide the base of the flap; Gigli's saw is absolutely necessary for this.

When the osteo-plastic flap has been turned down the operator can see the lesions of the internal table, generally much more extensive than those of the external table, and also the lesions of the dura mater and the brain; all this has been done without any rough manœuvre in the immediate neighbourhood of the wound, as the surgeon has always been working at a distance from it, and has in no way interfered with the damaged area. This, in my opinion, is the great advantage of this method whenever it can be employed, and this should be whenever the condition of the skull allows of a temporary resection, which is often the case. From this time forward the surgeon is no longer acting blindly, as he does in the ordinary method, and we shall now see how he should proceed.

Treatment of the Bone Injury

The internal table may be cleanly perforated. This is often the case with wounds made by bullets, and in such cases there is nothing to be done except to enlarge the orifice with gouge-forceps if the meningeal and cerebral lesions require a drainage-tube to be left in the wound. Much oftener one finds a depression of the internal table, a number of splinters of which are sometimes adherent to the dura mater which they have lacerated. Sometimes they even penetrate into the brain substance. The free splinters must be carefully removed, the large fragments still firmly attached by their bases to the rest of the bone-flap must be put back in place. In other words, the inner surface of the skull in the region of the wound must be smoothed off perfectly. All pointed spicules of bone must be cut off with the gouge-forceps. The flap is firmly held by an assistant, and all projections which are liable to press on the dura mater and the brain are gently chiselled away. Finally, the circumfer-

ence of the perforation is smoothed by removing all damaged pieces of bone with very sharp gouge-forceps.

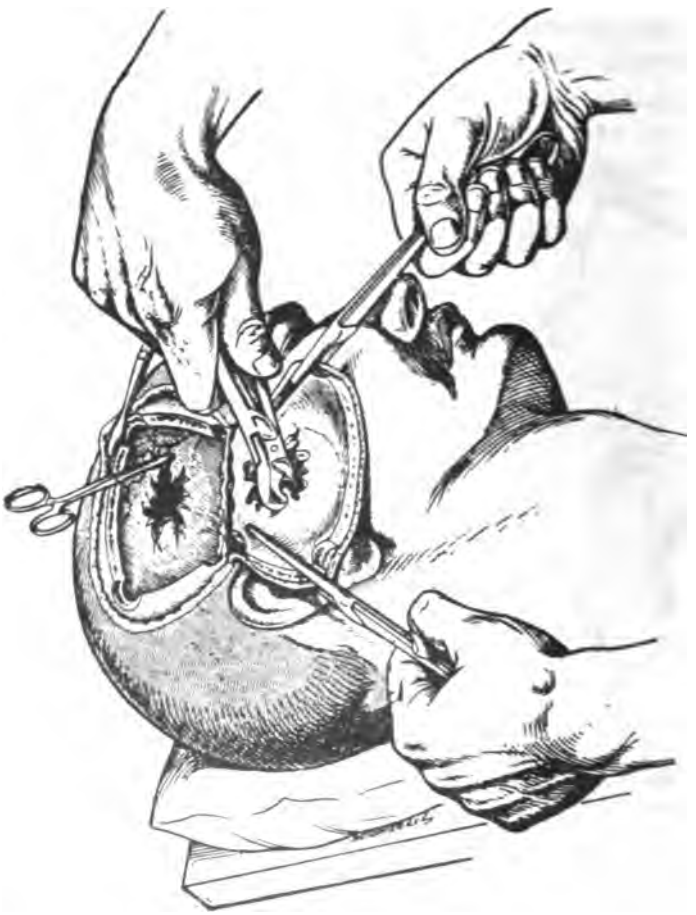


FIG. 42.—The flap being held quite steady by the assistant, the operator smooths off the orifice of entry of the missile from the internal aspect of the bone.

All these manœuvres should be done while the bone-flap is held firmly in strong forceps by an assistant (fig. 42). It is obviously much less simple than chipping away the skull with cutting pliers

haphazard and without any guide, but it is much more satisfactory from a surgical point of view. When the toilet of the inner surface of the bone-flap has been finished, the surgeon turns to the lesions of the dura and the brain, taking the greatest care meanwhile

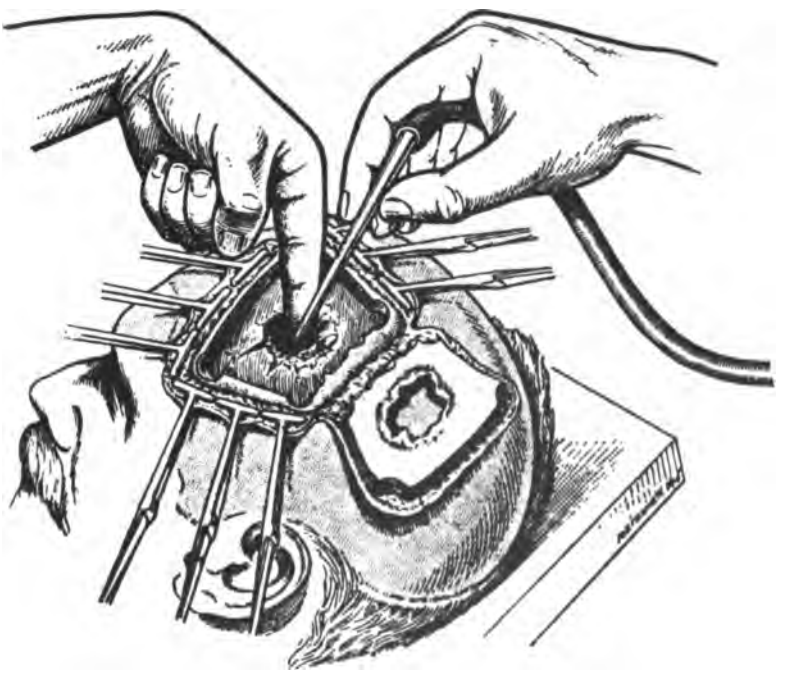


FIG. 43.—Prolonged irrigation with warm physiological serum is the best method for freeing the brain from the numerous and often very small and hardly visible foreign bodies.

not to disturb any adhesions that already exist between these two important structures. Detached splinters of the inner table are often adherent to the dura, and they should be removed with the greatest gentleness. If the dura has been torn and a portion of the skull is missing, the presumption will be that this fragment has penetrated the brain through the breach in the dura mater. Gentle search must be made for it there

with the tip of the finger and a forceps, and it will often be found. The lips of the wound in the dura mater must be trimmed, but as a rule this membrane should not be incised.

When the brain itself is injured, an effort must be made to cleanse the cerebral wound as much as possible, but even in this all excessive handling must be avoided. As a general rule one must be satisfied to do this cleansing through the wound in the dura mater just as it is and without enlarging it, but if it is necessary to enlarge it, it must be sutured again. Prolonged irrigation with warm physiological serum seems to me to be the best method of freeing the brain from the numerous and often tiny and hardly visible foreign bodies which it contains. With the finger introduced very carefully into the wound it is sometimes possible to feel the splinters, or even a projectile, which can then be removed with the forceps. The bottom of the wound is also irrigated by means of a glass canula pushed very gently along the finger; to be effective this irrigation must be prolonged, and while it is being carried out the patient must be told to cough or to expire deeply. In certain cases, under the influence of this expiration, the tissues of the wound are everted, as happens with the anus of a patient when he is told to bear down. The irrigation will then be very effective, and will draw out numerous foreign bodies which a rougher handling would have embedded deeply in the cerebral substance.

When the injury is deep and the brain substance around it is much damaged, it is advisable to insert a drainage-tube.[1] This emerges through the enlarged and trimmed orifice made by the missile, and should be withdrawn and cleaned at each dressing, and its

[1] I never use rigid drainage-tubes, but a layer of protective enclosing a small wick (cigarette-drain).

track irrigated for a long time with warm physiological serum so as to get rid of the necrosed brain matter.

When all these procedures have been completed, the osteo-cutaneous flap is replaced and sutured with great care. In order to make the suture exact and regular it is necessary to re-establish precisely the connections which existed between the flap and the rest of the scalp before the operation; this is greatly facilitated by the square form of the flap. A suture is passed through each angle of the flap and fixes it to each angle of the incision on the scalp. Then it is only necessary to suture the three straight incisions—a very simple matter.

The suture plays a most important part in regard to hæmostasis. Ligature of the scalp vessels must not be relied upon to stop the bleeding, but simply the exact apposition of the two edges of the incision by firm suture. While the density of the scalp makes ligature of its vessels very difficult, it also makes firm apposition effectual, where in softer tissues it would be useless. It is important that the two cut edges of a large vessel should be brought exactly face to face in the suture, so that the effects of the approximation shall be exerted equally on both of them. For this purpose the omega incision is much inferior to the rectangular one. When the corners of a rectangular flap have been once secured, each of its sides may be sewn up by interrupted or continuous sutures. The continuous suture is more hæmostatic than the interrupted ones, but it is necessary to remove all the forceps around the incision before applying it, and therefore the patient may bleed a little during its application. Interrupted stitches, well placed, effect excellent apposition and perfect hæmostasis, and they allow of the forceps being removed one by one. The continuous suture is much more rapidly inserted, but it sometimes gives

rise to small sloughs at the edges of the incision, especially if it be left in place too long. It is difficult and somewhat painful to remove, and its final results are never so perfect as those of interrupted sutures. One of the great advantages of the osteo-plastic flap is, that it can be raised again should it be desired to explore the dura mater and the brain anew, and as the suture may have to be repeated several times, it is better to use interrupted ones that cut up the edges of the incision less.

Whichever method is adopted, the sutures must be removed on the third or fourth day; this is the only way to get fine cicatrices, clean and without suppuration. The hæmostatic suture inserted at the base of the flap at the beginning of the operation should be removed at the end of twelve hours, but I have left it for twenty-four or thirty-six hours without any bad result.

This method of operation, as I have already stated, is only applicable where the skull is comparatively sound and allows an osteo-plastic flap to be cut. It would be absurd to be possessed with the desire to apply it in every case. It is excellent in all cases in which the internal table is broken but the external is only slightly fissured or depressed, since it allows the lesions to be treated without leaving a large gap in the skull, as is always the case in the ordinary procedure, in which the operator begins by removing a trephine circle in order to ascertain the condition of the internal table; if this be broken, he removes portions of the skull with cutting-forceps up to the limits of the fracture. In short, he replaces the fractured area by a large loss of substance, which has its inconveniences, since one of the principal occupations of the surgeons at certain neurological centres at the base is to repair these gaps by various measures, which I shall describe at the end of this

volume. By the method which I recommend the internal table is dealt with directly without touching the external table, and after the lesions of the dura mater, the sinuses, or the brain have been treated, the osteo-plastic flap is replaced without drainage, and after a short time the skull is as firm as ever.

This procedure is also excellent for wounds of the skull and brain when these structures have been struck at right angles to their surface. The lesion then is small, and even the most fervent partisans of drainage cannot claim any advantage in trephining widely. It is of doubtful value in tangential gunshot-wounds or deep furrows by shell-fragments. In these cases it would necessitate the formation of very large flaps, and I then prefer another method, which I shall describe later, but before doing so I wish to say a few words on the various difficulties that may be met with in cutting the osteo-plastic flap.

Difficulties which may complicate the cutting of an osteo-plastic flap.

It sometimes happens that the diploë bleeds freely while the bone is being perforated; it is best to finish the perforation without trying to stop the hæmorrhage. Then the walls of the opening should be smeared with Horsley's wax, which will attain the desired result.

The same thing may occur during the sawing of the bone. Here again the section of the flap must be completed, and it is here that the superiority of mechanical instruments becomes evident, as thereby the operation can be completed in a few seconds.

These hæmorrhages of the diploë are rare; a much more frequent form of hæmorrhage is that produced in the neighbourhood of the trephining when the bone is denuded of pericranium along the line of the incision. I shall return to this later on in connection with occipital and sub-temporal decompression,

where such hæmorrhages are especially serious, but I wish to point out here that the only means of stopping them is to drive a small pointed ivory peg into the orifice that is bleeding and then to cut it off flush with the surface of the skull.

Injury to the dura mater and the brain with Gigli's saw. —This accident will not occur if the trephine holes

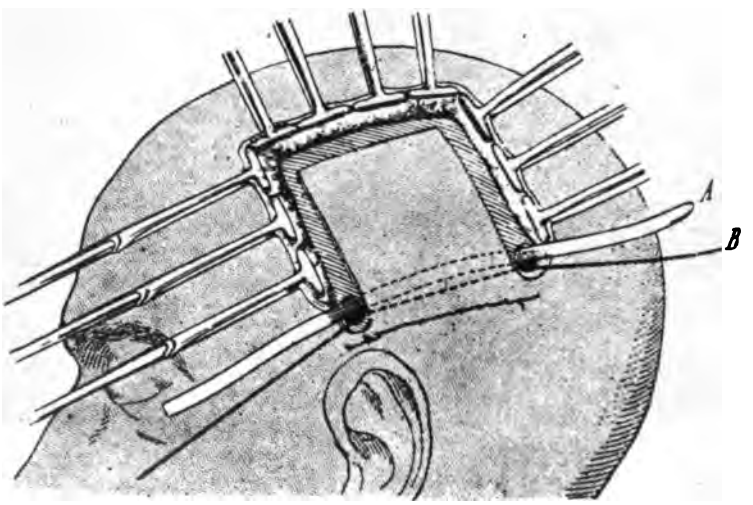


FIG. 44.—Gigli's saw has been passed under the base of the flap, but the dura mater separator is too narrow; it is unsteady in the trephine holes; the saw does not rest on it firmly, and may cut the brain.

are not placed too far apart, and if care is taken to use a dura mater separator adapted to the trephine with which the holes are made, and especially if watch is kept to see that the protective portion of the dura mater separator is well placed. As the saw represents the chord of the arc of bone which it has to divide, its tendency to penetrate into the brain will be greater the more convex the arc or the more distant the trephine holes from each other (fig. 25). If a large trephine is used and a narrow

dura mater separator, the protective portion of the latter moves about in the holes, and the saw may slip off the instrument and lie on the dura mater in places (fig. 44), but even in this event, if care has been taken at the beginning of the sawing to place the saw properly on the protector, the dura mater will not be wounded.

Rupture of the mengineal artery when fracturing the flap.—When the base of a flap is fractured and, as frequently happens, it lies over the lower part of the temporal fossa, it may happen that the middle meningeal artery may be torn while it is enclosed in the bone. In such cases it is first necessary to verify the position of the artery relatively to the bone, which is not always easy. For this purpose a current of warm physiological serum is very useful to wash away the blood as fast as it flows. If the artery is enclosed in a bony canal, the obliteration of this canal by an ivory peg is indicated, but often this is not the case, and the artery simply lies in a gutter of bone which, while not permitting of direct compression, hinders the application of a ligature. In this case the best thing is to free it for a certain distance by breaking away pieces of the bone above it with the gouge-forceps and then to tie it.

The opening of a sinus.—This accident must be looked for when raising a flap for a simple fissure of the external table seated in the median line or in the region of the lateral sinus. In fact, as has been often repeated, the internal table is often broken, and its fragments sometimes lacerate the sinus. I have several times found fragments of the internal table embedded in the sinus, which did not bleed until the splinter had been removed. In such cases the best method of hæmostasis is to apply to the vascular lesion a flap of muscle or aponeurosis. The suture of the sinuses is very difficult; it may even be said

to be impossible when there is any loss of the vessel wall, for the sinus walls are stretched and inextensible. It is in these very frequent cases of venous hæmorrhages that the superiority of local anæsthesia and the sitting position becomes evident. A hæmorrhage which is formidable in the horizontal position is rendered comparatively trifling as soon as the subject is in a vertical position. I borrowed this method of obliteration of wounds of sinuses by pieces of muscle from Sir Victor Horsley nearly seven years ago. During this period surgeons have made little or no use of it, and during this war my friend, Dr Velter, is the only one I have known to mention it. A short time ago Morestin described to the Société de Chirurgie an operation in which he vainly tried to suture a sinus. It is to be regretted that this technique has not received the official stamp, and has only myself for sponsor.[1]

The preceding remarks apply to the wounds placed under Classes 8, 4, and 1 in the classification at the beginning: they may be epitomised thus:—

8. Wounds in which the missile has struck the skull at right angles but without penetrating it; here both tables are broken, and the fragments of the inner one are often driven deep into the brain not far from the ventricle, which may be opened in the course of the operation, if it was not opened by the injury.

4. Wounds identical with the preceding, but in which the missile has penetrated into the skull; it then often lies deeper than the splinters which it has driven in with it.

1. Wounds in which the missile, having lost almost all its velocity, strikes the skull direct and produces a depression of the external table to which a fracture of the internal table may correspond.

[1] This method is in common use in the British services.—EDITOR.

All these wounds have one characteristic in common. The missile which produces them has struck the skull direct, and its passage through the bone is the shortest possible, so that while there is less shattering of the skull, the damage to the bone is of comparatively small extent. This is the condition for which the osteo-plastic flap method is most useful. Unfortunately in a number of very serious cases in which operation has much less chance of success, this technique can only be applied with great difficulty. This is when numerous and deep fissures proceed from the point of entry of the missile and break up the skull over a large area. Under these circumstances the idea of cutting an osteo-plastic flap must be given up, and I consider that the best plan is to adopt the procedure which I shall now describe. It is the same with tangential gunshot-wounds.

Use of Mechanical Instruments

I wish to say just a word regarding operations as performed with my set of instruments, because very few surgeons possess it, and because for the last two years I have probably been the only one to use it regularly. I shall describe it, because I owe to the operative facility that it gives me the idea of systematically cutting temporary osteo-plastic flaps whenever that is possible. It is a very strong and simple set of instruments, and consists of an electric motor, or a motor of my own invention set in motion by an assistant, who may be a woman or a child: I prefer this latter motor, because it does not get out of order and can be used anywhere. I shall not describe it, as an examination of the illustration will show the mechanism plainly. The motor, whichever is used, is connected by a cable to a sterilisable tool-holder which is manipulated by the surgeon. My trephine and its bit (figs. 18

and 48A), or my vertical brace and its protector (figs. 46 and 47), can be mounted on this tool-holder in turn. I shall not attempt to give the details of my trephine; sufficient to say that no matter what force may be put on it, it will pierce the skull without wounding the dura mater or the brain. The proposed

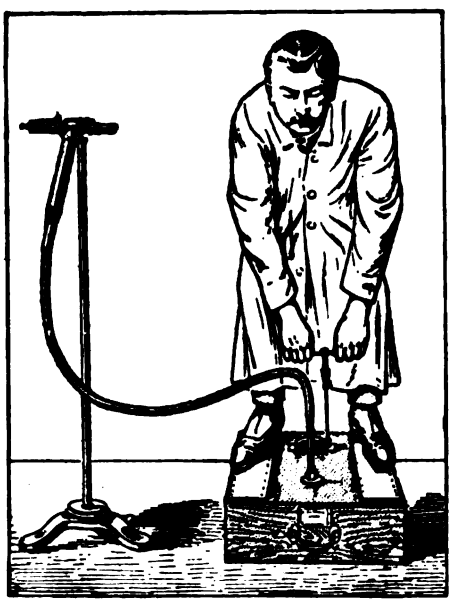


FIG. 45.—The author's motor, which is very strongly made, consists of a horizontal fly-wheel with ball-bearings, and is set in motion by a cog-wheel.

osteo-plastic flap being marked out by the incision in the scalp, I pierce a hole at one of the lower corners of the flap and then, substituting the vertical brace for the trephine, I cut three sides of the flap, and fracture the fourth by means of the special apparatus which I designed for that purpose.

The whole operation requires only two to three minutes, and is admirably borne by the patient, who is not made unconscious. It must be stated that the

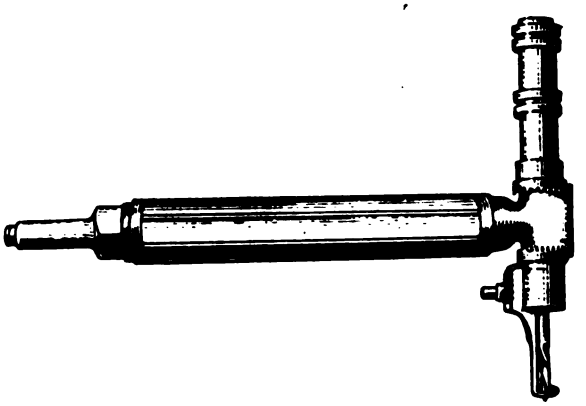


FIG. 46.—The author's vertical brace.

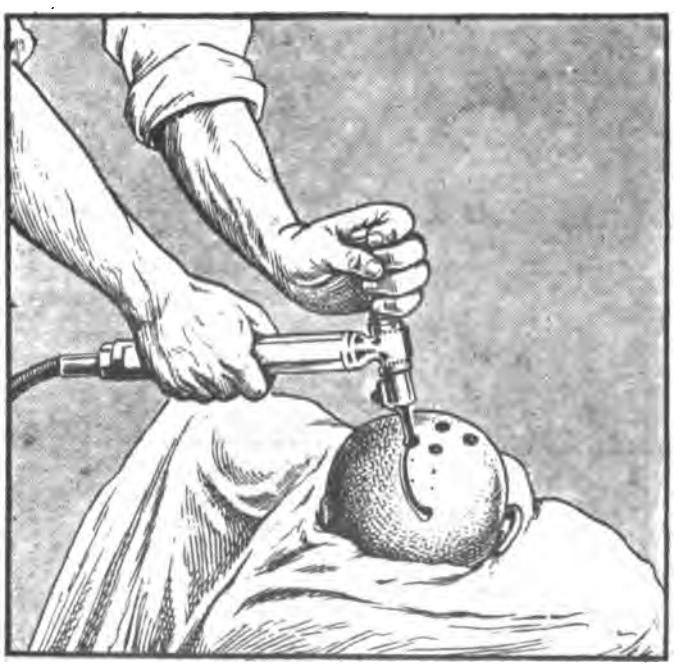


FIG. 47.—Method of using the vertical brace.

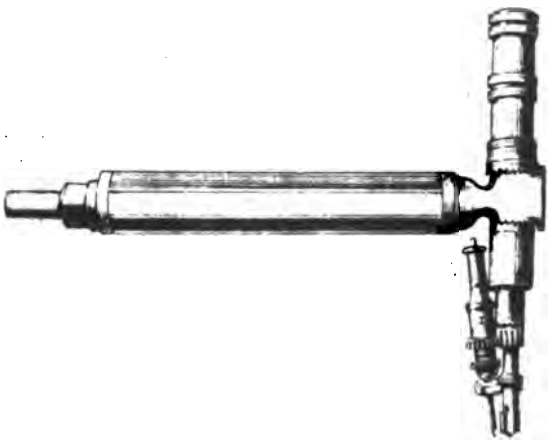


FIG. 48.—The author's perforator.

FIG. 48A.—Manipulation of the perforator.

patient makes no complaint of the vibrations of the instrument; this is a reply to the objection raised by some surgeons to this method.

Treatment of a Gutter-wound

When the skull is ploughed by a missile which has taken a more or less tangential direction relatively to its surface, the cutting of a temporary osteoplastic flap is unfortunately no longer possible, and the operator must make up his mind to adopt another and much more destructive method. The end proposed remains the same: to get rid of the mechanical conditions due to the fracture (compression by splinters, and blood-clots), to arrest the hæmorrhage, to clean the area of the wound by removing all free splinters, and facilitating the elimination of all dead material in its neighbourhood, and all this without adding to the injury or using rough or rash manipulation.

To this end I believe the best way is to cut a broad, rectangular scalp flap, following exactly the procedure pointed out above, but in this case the basal hæmostatic suture can be dispensed with. The real object of this suture is to allow of the removal of all the forceps from the edge of the flap when it is not desired to loosen it from the surface of the skull which it covers, because these forceps would be very much in the way when the bone-flap was cut. But in the present case the flap is turned back away from the field of operation, so that the forceps fixed to its edges are not in the way, and it is sufficient to remove the flap and forceps from the field of operation for them to give no more trouble (fig. 49).

The dimensions of the cutaneous flap should be a good deal larger than those of the wound. The osseous lesions are frequently more extensive than the cutaneous ones, and it is desirable that the former

should be completely visible when the flap has been reflected.

In these tangential wounds the operator finds himself confronted by a more or less deep furrow

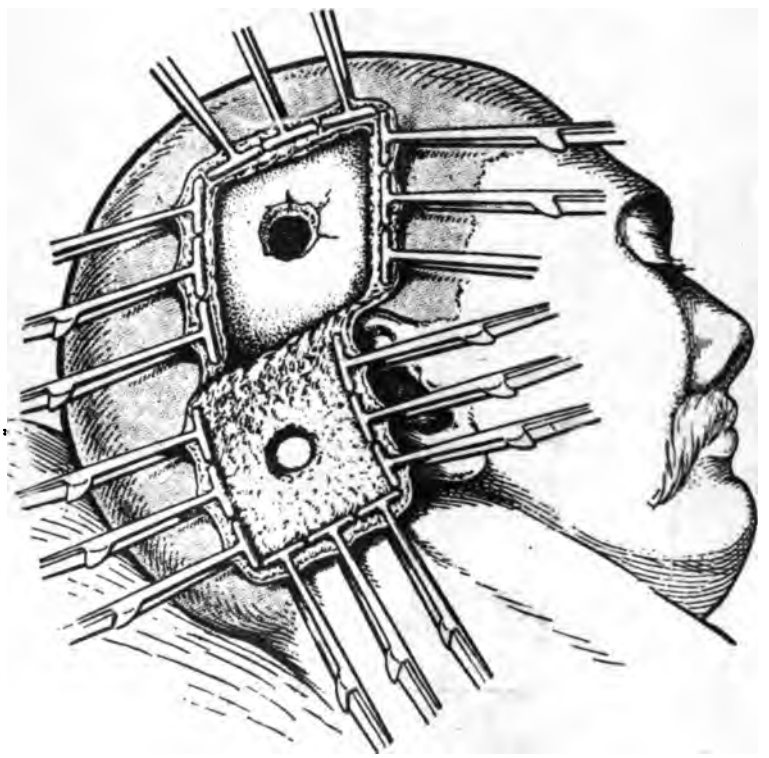


FIG. 49.—The flap being turned back, away from the field of operation, the forceps fixed to its edges are out of the way, and it is sufficient to cover over the flap and forceps for them to give no more trouble.

in the brain substance itself. Some splinters may penetrate the brain, but, generally, they are superficial, and are not deep in the interior, as is so often the case in apparently less serious wounds produced by missiles striking the skull direct.

The edge of the osseous furrow must be trimmed with the gouge-forceps and healthy dura mater ex-

posed; but in doing this, as in all other surgical operations, I am of opinion that an effort should be made to proceed from the sound to the damaged area, and that it is often dangerous to pass the jaws of the gouge-forceps below the edge of the bone into the damaged region, where there is so much alteration in the structures that it is impossible to get one's bearings clearly. There is a risk of increasing the damage, of driving in detached splinters which have not yet penetrated the brain, and also of lacerating the dura mater, or of increasing its laceration if it is already opened. The best thing is to trephine about half an inch from the edge of the bone outside the damaged area.

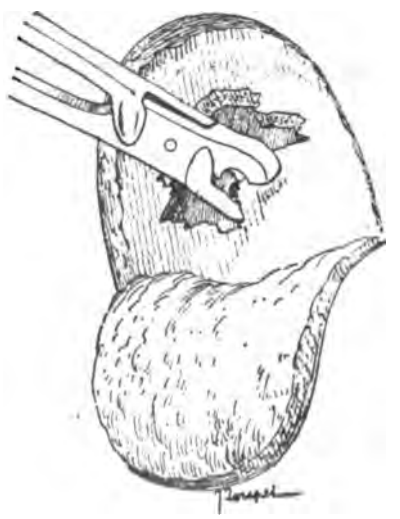


FIG. 50.—Trimming up the hole in the skull with the gouge-forceps. Care must be taken to avoid using these forceps as a lever and fracturing the cranium rather than cutting it.

If instead of finding the dura mater intact when it is uncovered, lesions are found extending further than was expected, as often happens, this is got over by trephining again further out. Starting from this opening, a channel is cut with the gouge-forceps direct to the damaged bone. In this way the limits of the injury are thus made evident, and it is then easy to expose it without doing any further damage.

If the dura mater is intact, it is not to be opened on any pretext. It is impossible to emphasise this point too strongly. To open the dura mater in order to evacuate a hæmatoma, or the pulped brain

resulting from a violent contusion, is to infect almost certainly a focus till then aseptic, and to invite meningitis and encephalitis. Nevertheless there are many surgeons who do this. If, however, the dura mater is injured, if the pulped-up brain matter is

FIG. 51.—This apparatus, which has been constructed by M. Adnet in accordance with my instructions, allows one to irrigate the brain with warm serum. In order to vary the temperature of the serum it is only necessary to plunge the tube into boiling water. The temperature of the water is read on a thermometer mounted immediately above the canula.

escaping through the opening, if the dura although intact is immobile and blackish, if the existence of a hæmorrhage or an area of softening can be made out, it is quite logical to enlarge the meningeal opening and to evacuate this already infected focus as gently and as completely as possible. The dura mater must be subsequently sutured with care, except about its

laceration; here a cigarette-drain must be inserted, as it has the advantage of not being rigid and of not sinking into the brain substance. Nothing is more difficult than completely to empty these collections of blood, pulped-up brain matter, and splinters without

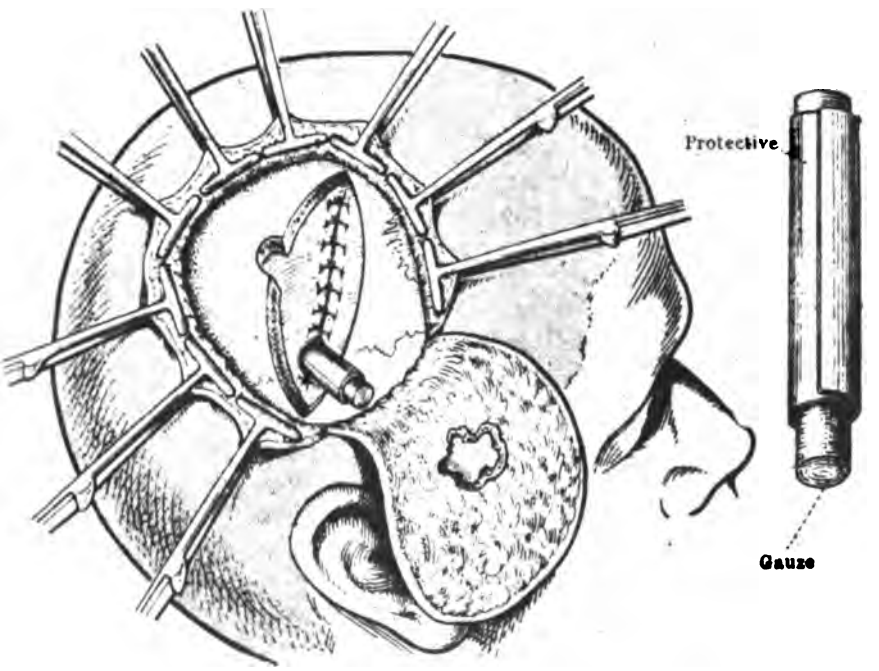


FIG. 52.—The incised dura mater has been sutured, and a cigarette drain left in the wound.

injuring the healthy brain tissue which forms the wall of the cavity. The best plan is to feel about with the finger very gently in all directions under a continuous current of warm serum (45 to 50° C.). While this is being done, the patient is told to expire forcibly or to cough, which causes the walls of the cavity to become everted, and makes them more accessible. The finger should be moved methodically and with great gentleness in every direction; sometimes

it will feel a splinter or some foreign body, which is then withdrawn with forceps. The employment of the warm serum has great advantages; it is very hæmostatic, and by its mechanical action flushes away a quantity of scarcely visible, but often very infective, débris. But it must be remarked that it is very badly tolerated by a patient under local anæsthesia whose integuments have to be protected with an aseptic mackintosh sheet.

Nothing is more difficult than to define exactly the limits of trephining of this kind. To read certain works published on the subject, it would seem as if it were only necessary to remove its bony covering from the brain to ward off all the complications of an extensive cerebral injury, and that from the moment the injured organ is laid bare over the whole extent of the lesion everything has been done that could be done. This radical removal of bone without regard for any other considerations appears to me to be empirical and devoid of any scientific basis. I know of many wounded men who have recovered quite well without having undergone extensive interference of this kind, and I, personally, remain very strongly opposed to great mutilations which are justified by nothing except the desire to do something at any price, even where nothing useful can be done. When an attempt is made to expose the entire extent of a superficial cerebral wound in order to keep it under supervision, to apply a flat dressing, and to avoid the formation of an abscess below the contused or broken bone about it, this is all quite defensible. But when fissures are followed up and large areas of the skull are removed which have no immediate relation to the deep track in the brain, I cannot understand it at all.

In those more or less tangential wounds of the skull, for which the osteo-plastic flap is not suited.

there are often large losses of the scalp. The bone opening, when it has been trimmed up, is nearly always larger than that in the scalp, and it is common for the dura mater also to be damaged to a great extent. The brain, which forms the bottom of the

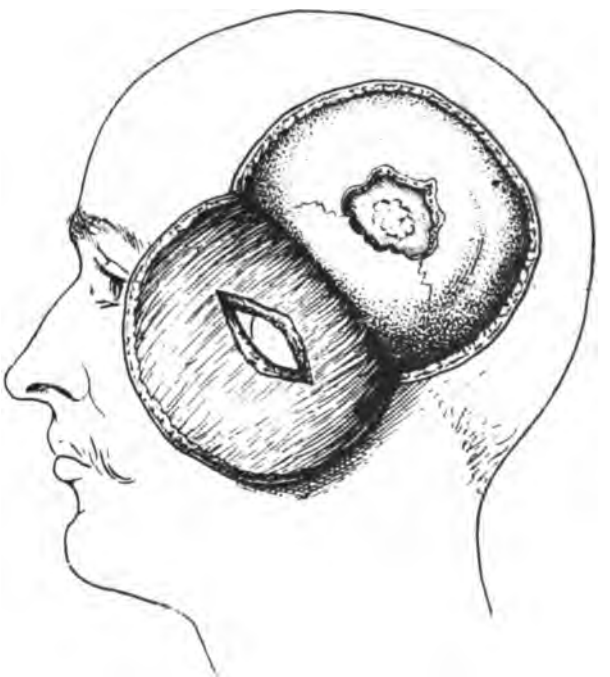


FIG. 53.—Raising the scalp-flap, in the centre of which a hole has been made by the missile.

wound, is thus exposed, often for a long time, and it therefore gets infected and often herniated. To guard against these two dangers, infection and hernia, Sargent proposed the ingenious plan of loosening the epicranium from the scalp in such a way as to allow it to slide and to be sutured beneath the orifice in the latter. The brain can thus be perfectly covered in, and the cutaneous wound quickly cicatrises. Drainage is effected by two tubes which protrude

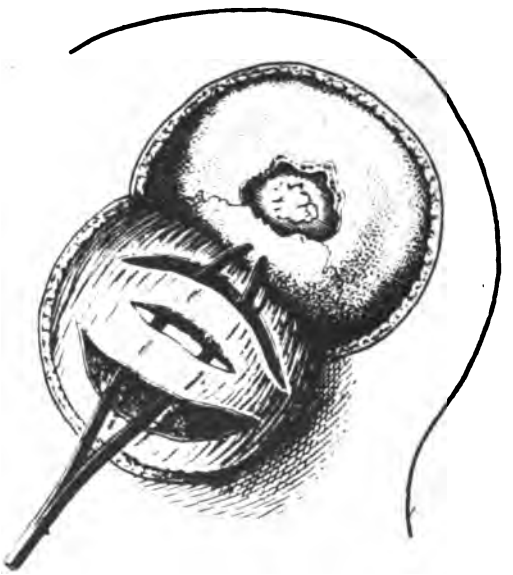


FIG. 54.—Freeing the epicranium on each side of the orifice.

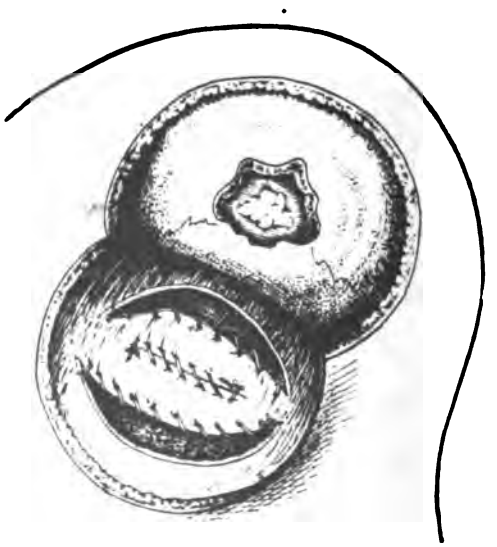


FIG. 55.—Suture of the freed epicranium and obliteration of the orifice in the scalp made by the missile.

from the inferior angles of the flap. The accompanying figures (53–57) borrowed from an article by Sargent will make his method clear.

I have described two methods of operation which appear to me to be the best, and between which a choice can be made according to the case. Preference will be given to the osteo-plastic flap whenever it is practicable, because it offers many advantages. This flap can be made whenever there is the least doubt as to the condition of the internal table or of the brain, and it must be remembered that a small depression in the external table, especially when it is situated in the middle line over the longitudinal sinus, often gives rise to serious trouble. It must also be remembered that sometimes a very small missile may traverse the skull, scarcely leaving a trace, and may nevertheless cause deep cerebral and vascular lesions. The osteo-plastic flap leaves no trace nor any deformity, and it always effects a cerebral decompression by which the patient is benefited; it does not cause cerebral herniæ of mechanical origin, as the small classical trephining so often does. It gives a very wide view of the lesions, and that as often as desired, since it can be reopened whenever it is thought necessary.

The second method described, the enlargement of the opening in the bone with the gouge-forceps, has none of these advantages, but it is indicated whenever the bone injury is considerable and does not allow an osteo-plastic flap to be made.

The results obtained by these two methods depend entirely on the condition of the dura mater and the brain. Whenever the dura mater is intact there is good ground for hoping for a cure, for the two chief complications of wounds of the skull, meningitis and encephalitis, are then avoided. Deep wounds of the brain at right angles to its surface, with splinters

FIG. 56.—Aspect of the flap at the end of the operation; the brain is no longer visible, and is covered by the epicranium.

FIG. 57.—Aspect of the region operated upon a few days after the operation.

driven down not far from the lateral ventricle, are the most dangerous. They often appear to get cured, but at the end of a variable time encephalitis makes its appearance and then ventricular meningitis, and the wounded man, reckoned as cured by a surgeon at the front, dies at a base hospital.

Surface wounds of the brain, in which the skull is opened along a plane tangential to the cerebrum, do much better. In these wounds the splinters are generally much less deep than in the preceding one, the ventricle is further from the seat of infection, and a flat dressing can be applied. There is no septic retention, and there is some hope of saving these patients.

Between these two extreme types are grouped all the intermediate ones. The surgeon must allow himself to be guided in their treatment by the few general principles laid down above, which are: the almost absolute impotence of the surgeon against cerebral infection, and the necessity there is not to counteract, by ill-timed treatment, the efforts which nature is making to limit the extent of the septic focus; the utility of working from healthy towards unhealthy regions; and not to operate haphazard.

CHAPTER XVIII

SEQUELÆ OF OPERATIONS

Immediate Sequelæ

THE sequelæ vary greatly according to the case.

When the patient is fully conscious at the time of the operation, and presents few or no abnormal symptoms, it must be hoped that he will still be in the same condition after the operation, because any fresh symptoms that he may then present will be almost certainly associated with the appearance of meningitis or encephalitis, or will be due to the operative interference.

When the patient presents abnormal symptoms before the operation these will increase or diminish according to their cause, without the surgeon being able to draw therefrom any inferences as to the ultimate cure.

What I mean is this: a patient with increased intracranial pressure (severe headache and vomiting) will be almost immediately relieved by the operation without being in any way safeguarded from grave infective complications. In the same way a patient who shows signs of compression by fragments of bone or blood-clot has a very good chance of having his condition improved after trephining. On the other hand, a subject of traumatic œdema of the brain (paralysis, hemiopia, and aphasia) will often

have his troubles temporarily aggravated after the opening of the skull. It is true that if the œdema is really the only cause, all the morbid phenomena will begin to improve at once, and will finally disappear. On the contrary, if the œdema of the brain plays only a subsidiary part, and if the symptoms are essentially due to destruction of the brain substance, little or no improvement will occur. When the patient is comatose he may become sensible in a few hours; it is then merely a case of cerebral concussion, or perhaps of compression of the brain by hæmorrhage or splinters, and the compression will cease after the operation. But he may remain comatose, and then he will die, because his condition is due to a laceration of the brain incompatible with life, against which operation is powerless.

In short, free opening of the skull in the damaged area for the purpose of trimming and cleaning it up, and of preventing the comparatively tardy infection symptoms, also modifies the immediate symptoms provoked by the wound; by giving room to brain which is œdematous, or compressed by blood or splinters, it alleviates the signs of hypertension, especially the severe headache. By decompressing the brain over the damaged area it exaggerates the functional symptoms connected with the local œdema, and when a hemiplegia, a monoplegia, an aphasia, or a hemiopia are primarily due to the œdema, it is certain that these phenomena will be aggravated immediately after the operation, and will disappear afterwards if no infection appears to complicate matters. It removes the signs of direct compression by splinters; as, for example, Phocas's patient, who entered the operating room blind, and left it with almost normal vision.

It is without effect on destructive lesions.

Post-operative Treatment

A patient with a skull-wound must be dressed on the day following the operation. The incisions in the scalp, even when well sutured, always give rise to free oozing, and as a rule the dressing is completely soaked with blood at the end of twenty-four hours.

I always drain with a cigarette-drain, never with a drain made of resistant tissue. I never use drains of gauze; nothing is more provocative of the retention of septic fluids or more favourable to infection. A gauze drain placed directly down the track of the injury adheres to its walls, obliterates it, and when removed gives rise to bleeding from it, and thus opens the door to infection through a multitude of small oozing vessels. A cerebral drain should be of soft material which has no tendency to adhere. When a rigid drain is placed in contact with nerve tissue it ulcerates it and hollows out a bed for itself. It may thus open the ventricular cavity, which is often very near the bottom of wounds running at right angles to the surface of the brain.

The cigarette-drain (fig. 52) is made of a strip of varnished taffeta or of thin rubber rolled round a roll of gauze. The gauze is thus isolated from the walls of the track. Its part is merely to draw outwards, by capillary action, the fluids which accumulate at the bottom of the wound. At the first dressing the cigarette-drain is withdrawn, the gauze which it contains is changed, and is replaced after irrigating its track with an antiseptic solution.

The hæmostatic suture which I place along the base of the flap is removed at the first dressing. It has happened to me to leave it for several days by an oversight, and though it gave no trouble I consider

it preferable to remove it as soon as hæmostasis is assured by the commencement of cicatrisation.

Very often considerable œdema of the eyelids and the base of the orbit is observed as a sequel of lateral trephining; this is of no moment.

In cases that do well, union of the flap is complete by the fifth day. The sutures are removed on the fourth or fifth day at the latest; there is no advantage in leaving them longer, and at the end of that time they begin to cut through the scalp and cause suppuration.

During the whole post-operative period, as long as the patient cannot be considered cured, the scalp must be kept shaved over all the operation area, and especially around the circumference of the original wound; the drain generally emerges in this area.

When should the drain be withdrawn? Nothing is more difficult to decide, because very often it is just after its removal that a cerebral abscess begins to develop, and necessitates the opening up of the track and fresh draining. I am of opinion that it is best to allow the wound to heal from the bottom, and to shorten the tube in proportion as it is pushed outwards by the new tissue.

The post-operative treatment is not limited to this. The patient must be watched very closely; the surgeon must remember that many complications may supervene in the succeeding weeks or months. A number of men with head-wounds die ten, twelve, fifteen, or eighteen months after the operation which was assumed to have completely cured them. Nothing is more discouraging than these delayed deaths, which are nearly always due to an abscess which develops at the spot from which the projectile was extracted a long time before, leaving absolutely nothing to inform the surgeon at the base as to the probable seat of the lesion, as the cerebral abscess very often

develops without any symptom which allows of localisation. I shall return a little further on to this very interesting point when dealing with the extraction of foreign bodies and the treatment of cerebral abscesses.

Meningitis

Acute diffuse meningitis is without doubt the most formidable of all the complications of wounds of the skull, as it kills the patient in the period immediately following the wound. It never shows itself in wounds of the skull which do not involve the dura mater, and it is probable that in the few cases described as exceptions to this rule there was fracture of the vault spreading to the base, or even extra-dural collections opening into the subarachnoid space (see de Joltrain).

As I have said several times, it is common for a missile fracturing the vault of the skull to give rise to fissures which often extend a long way down to the base. These fissures nearly always lacerate the dura mater, which is very adherent in this region, and the sub-dural space may then communicate with the exterior by means of the ear or the nasal fossæ. From this special point of view the use of the gouge-forceps to break away piecemeal the edges of a bony gap in the vault is very bad when there are fissures. With the gouge-forceps the bone is fractured by a powerful levering and rocking movement rather than cut. In the course of this, fissures of trifling length may be extended into the base of the skull.

Fractures of the vault without basal fissures and without damage to the dura mater are so trifling, that they should not be classed in the same category as fractures of the skull with meningeal lesions. Wounds of the skull with an injury of the dura mater are always very serious, and frequently become the seat of meningitis. The infection of the meninges, as I

urged at the beginning of this book, is contemporaneous with the wound, but at that moment it is a meningitis localised to the circumference of the damaged area. The œdema of the brain applies the surface of the organ firmly to the deep aspect of the dura mater, and favours the formation of adhesions and limitation of the infection; but unfortunately this does not always happen. Is it possible to prevent meningitis by operation? I have but little faith in it, and I am convinced that the best chance of avoiding it is rather by abstaining from any interference, however slight. If, however, one studies the publications which have appeared during the last two years on this subject, one finds that surgeons have the idea that early operation, particularly in the form of wide removal of the skull and removal of all splinters, is especially potent against this accident. It would seem as if the mechanism by which these practices are to be carried out were evident, because nobody takes the trouble to give any information on this subject. It seems that the rule is to open up the wound widely, whatever may be its seat, without paying any regard to its topography, and this is an excellent rule, but it is a mistake to imagine that a deep wound of the brain can be opened up by trephining the skull over it. As a matter of fact, nothing is laid open by such an operation; all the ramifications of the brain-wound have not been laid bare, nor has a tunnel filled with infective fluids been converted into a wide-open and easily-drained trench. Even if this had been done, it might be a useful precaution against encephalitis, but not against meningitis. Attentive reflection on what goes on at the periphery of the meningeal wound will enable one readily to understand that any introduction of instruments between the meninges and the brain can only carry the infection a little further

forward below the dura mater, and it is certainly best to limit oneself to practising a cautious trephining, as I have pointed out above.

Some authors have recommended repeated lumbar punctures on men with skull-wounds in order to prevent infection of the meninges. I must confess that such a practice appears to me utterly incomprehensible. The first effect of lumbar puncture is to diminish the volume of the brain, which in shrinking detaches itself from the meninges to which it was adhering. The sub-dural space from being practically only a potential cavity thus becomes a real one, and opens itself widely to infection; this is all that is gained.

Later on, when meningitis is established, and in order to do something, a fairly large quantity (20 to 30 cubic centimetres) of cerebro-spinal fluid can be removed by puncture and replaced by 15 to 20 cubic centimetres of electrargol. This practice is justified by the following reasons: In the course of acute meningitis there is always great hypertension, which is diminished by puncture. Puncture, by diminishing the quantity of the cerebro-spinal fluid, at the same time diminishes the quantity of the toxines contained in it. The injection of electrargol perhaps acts as a microbicide and antitoxic. By following this method I have certainly seen some cases of acute meningitis cured, but I have seen very few, and it is also possible that they might have got well by other treatment, or by none at all.

To sum up. There is no treatment for acute diffuse meningitis. Preventive treatment of this formidable complication consists, in cases of wounds of the skull without lesions of the dura mater, in treating the bone lesion so as to prevent the formation of an intra-cranial abscess. (The frequency of the formation of these abscesses and their opening into the

subarachnoid space through the ulcerated dura mater is far from being proved.) The treatment, in cases of wounds of the skull complicated by injury to the dura mater and lesions of the brain, consists in trephining with extreme caution, and interfering as little as possible with the protective adhesions already formed.

Finally, when the gouge-forceps are used the greatest care must be taken to use them as a cutting rather than as a breaking instrument.

Encephalitis and Cerebral Abscess

The patient who escapes meningitis during the ten days or fortnight following on his wound has great chances of not succumbing to this complication, but for weeks and months he continues to be threatened with encephalitis. During my stay in the base hospitals I saw many trephined patients who to all appearance had long been cured die of this complication. The general condition of such patients declines progressively, but they present no clear symptoms. They get thin, lie in bed, have no energy, and after remaining for a varying time in this condition, they suddenly die. Against such accidents the surgeon is entirely unarmed if the infection does not localise itself. But, fortunately, the encephalitis often gets localised, and a cerebral abscess makes its appearance. The abscess has no clear symptoms any more than the encephalitis, which allow one to diagnose or locate it. But when a patient begins to go downhill, no matter at what period of the case, this complication must be thought of and action taken accordingly. The encephalitis and the abscess develop around the missile when it still lies in the brain, or else in the damaged zone when there is no missile present. In the latter case the abscess is generally superficial and easily accessible.

I shall consider in succession the various cases which may arise.

1. *The wound of the skull and brain was comparatively superficial, and there has never been a projectile enclosed in it.*—In this case a temporary osteo-plastic flap must be raised at the level of the scar and the dura mater widely exposed. Generally the latter does not pulsate. Most often it is adherent to the brain over a wide area, and special care must be taken not to destroy these adhesions. The brain is often slightly herniated through the old wound in the dura mater. At this point a large needle may be pushed into the brain without any risk of infecting the meningeal cavity bearing in mind the situation of the ventricle. The needle is pushed steadily onwards, and when the pus is found it is evacuated by an incision parallel to the direction of the subjacent convolution, through the old laceration in the dura mater, and as far as possible without going beyond it. Drainage is effected with a cigarette-drain, which emerges through the opening in the bone made by the projectile in the centre of the osteo-plastic flap. Subsequently prolonged irrigations are carried out with warm dilute iodine solution. The drain should not be withdrawn as soon as the oozing of pus has ceased, for early removal is often followed by rapid re-formation of the abscess.

2. *When there is a retained missile.*—In the great majority of cases of this type the abscess forms round the foreign body, and the best way to evacuate it is to extract the latter (see Extraction of Projectiles).

3. *When there has been a missile embedded but this has been extracted long before the formation of the abscess.*—These are certainly the most puzzling cases. If the missile was seated in the centre of the damaged area the abscess will be there also, and will be easy to find; but it often happens that the projectile is

situated a long way from the area of the injury, and the abscess which develops around it, or rather round the foreign bodies which it has drawn in with it, is far from the lesion in the skull. The situation of the latter is therefore no guide to the abscess, which will be very difficult to find in the absence of a projectile, unless this gives rise to localising symptoms.

It would be a good thing if surgeons at the front would tattoo on the scalp of the subjects they operate upon the three points used for the employment of Hirtz's compass when the foreign body was removed, and that they should give each patient the radiographic diagram necessary for this. Then the surgeon at the base will be able to centre the instrument, and to approach with much greater chance of success many abscesses which do not give any localising symptoms.

Cerebral Hernia

The causes of cerebral hernia are various; it sometimes indicates hypertension of the cerebro-spinal fluid symptomatic of a ventricular meningitis which most frequently ends fatally. This kind of hernia is analogous to that observed in patients who have had a decompression performed with incision of the dura mater. It diminishes under the influence of lumbar puncture and increases when the patient is in the horizontal position. If it be punctured, it is easy to tap the dilated ventricular cavity, and more or less modified cerebro-spinal fluid is withdrawn. This kind of cerebral hernia in a patient with a head-wound has an indifferent prognosis. Its treatment is one of those which is set up against meningitis in vain.

Beside cerebral hernia due to hypertension, we must consider that which often accompanies a cerebral abscess developed about the area of injury. The

mechanism of this is easy to understand. That portion of the brain in which the abscess is developing increases in volume and projects outwards. To this cause, as in the preceding case, is often added a certain degree of hypertension of the cerebro-spinal fluid. The puncture of such a hernia must be made with a trocar large enough to give free passage to more or less thick pus. It will often be necessary to practise aspiration by means of a syringe, therefore it is well to have one with a nozzle adaptable to a trocar or a very large needle. If necessary Potain's apparatus can be used, but only a very low vacuum should be employed, otherwise the cerebral substance will be drawn into the needle, which will get stopped up. The treatment of this form of hernia is similar to that of the cerebral abscess, of which it is symptomatic. The brain must be incised over it and drained (see Cerebral Abscess).

In both the cases just described the cause of the hernia is primarily an increase in the volume of the brain combined with dilatation of the ventricular cavities or the formation of an abscess, but as soon as the hernia is formed it protrudes from the skull through the trephine hole, and then there may be strangulation of its pedicle by the orifices in the dura mater and bone through which it passes. Œdema of the herniated portion then occurs with vascular thrombosis and sloughing. These phenomena are of only secondary importance when they are merely symptoms added to the alarming syndrome of meningitis or cerebral abscess, but they become of primary importance in those early hernias of which the mechanism and the treatment have been so well studied by Leriche (Leriche, *Lyon chirurgical*, May–June 1916).

Apart from any infection of the meninges or the brain, the latter becomes swollen and œdematous in

the region of the damaged area. This is a general result of contusion, whatever organ be affected.

At the beginning of this little work I laid great stress on this local œdema, which applies the brain to the deep aspect of the dura mater and isolates the great meningeal cavity from the infected region by allowing protective adhesions to form, and strongly urged the necessity of not breaking down these adhesions. This œdema of the brain certainly favours the formation of a hernia through the aperture in the skull. If, in addition, the patient is operated on with his head low and under chloroform, or if he vomits during and after the operation, there will be a still greater chance of a persistent hernia being produced. Its strangulation by the dura mater and the bone causes further increase of its volume. This strangulation is proved by the deep furrow to be seen in the pedicle of these hernias when it is freed by enlarging the trephine opening. The mechanism of these hernias is one of the reasons which make me recommend the large temporary osteo-plastic flap. By this method the damaged region is very widely decompressed, and the brain heaves up the whole flap instead of entangling itself in the bony gap in its centre. Unfortunately this method of procedure is very little known.

The course of these hernias is variable. Some diminish and are cured spontaneously. In other cases the herniated brain tissue, which is always much smaller than it is thought to be, becomes gangrenous, and the portion which forms the base of the hernia gets covered with granulations which undergo cicatrisation. In other cases the herniated cerebral tissue gets infected progressively, and a slow form of encephalitis may end in death.

The formation of these hernias must be avoided as much as possible. To this end the operation must

be performed under local anæsthesia, which avoids vomiting and the increased intra-cranial pressure that results from it, and with the patient sitting up in order to avoid congestion of the cerebral veins and the increase in volume of the organ which it entails. Whenever it is possible, a temporary osteoplastic flap is cut in the way already described. This flap widely decompresses the brain and allows itself to be pressed up, and so gets rid of most of the conditions favourable to the formation of cerebral hernias of mechanical origin. When the hernia has formed, it seems that the best thing, as Leriche has clearly pointed out, is to enlarge the trephine opening until healthy bone and dura mater are exposed. This is the essential part of what he says on this subject:—

"Early cerebral hernia is seen after inadequate trephining. They are really perfectly curable if we regard them as the mechanical result of a permanent local irritation due to an inadequate trephining, and treat them by enlarging the opening in the bone until we meet with healthy dura and brain tissue.

"Early cerebral hernia appears as the result of a phenomenon which is primarily mechanical and vascular, and everything goes on as if the hernia were caused by a local œdema of the contused brain, pushing it through the opening in the dura and getting it strangulated there because an inadequate bony opening causes faulty circulatory conditions to persist in the contused area.

"The displaced and contused brain matter occupying more than its normal space is cooped up in its envelopes and seeks for more room. In order to effect a cure it must be given room by performing a local decompression. Cerebral wounds, like every serious wound received in war, can only be cured by being given plenty of room; therefore the opening in the bone must be enlarged.

"Where this has been done, and the stricture at the base of the hernia has been relieved, the course of the hernia is as follows :—

"1. The hernia first increases in volume because its tightly grasped pedicle broadens out and the dura mater in the affected area is no longer restrained by bone and protrudes. Sometimes there is a temporary exaggeration of the objective symptoms (paresis), but as a rule the patients are very soon better.

"2. At the end of a fortnight, seldom sooner, and sometimes after two or three days of pyrexia, the hernia is seen to shrink a little without apparent cause.

"3. After this it will be noticed that the hernia pulsates more strongly, and its size varies according to the position of the head It diminishes when the head is erect, and increases when the patient lies down. This phenomenon is very surprising when first seen. This is the explanation: The hernia consists of a cerebral base surmounted by a layer of blood-clot and more or less waxy granulations with a necrotic aspect. When the process of cure is well started, this superficial stratum, which appears to be rather thick, becomes continuous with the dura mater, which it seems to prolong; the demarcation between the two can no longer be seen, and, in fact, this is a layer which becomes organised and forms the future dura mater or, rather, the newly-formed fibrous lamina which will represent it.

"Little by little, and no doubt partly as a result of the pressure that the cerebral-spinal fluid is always exercising around the neck of the hernia, and partly as a result of the pulsation of the brain, cleavage occurs between the two strata composing the hernia, and the brain parts company little by little with its limiting membrane.

"If lumbar puncture be performed at this stage the hernia sinks down completely, and there is a deep intra-cranial depression over which the edges of the bony gap can be made out. But lumbar puncture provokes violent headache, and is often followed by a mild attack of meningeal inflammation. It serves no useful purpose to provoke this even if it is not dangerous, and therefore I never do lumbar puncture at this stage."

The cutting of an osteo-plastic flap with the orifice which gives passage to the hernia as its centre is an admirable substitute for the enlargement of the bony gap suggested by Leriche.

Epilepsy

Epilepsy is a common and comparatively late complication of injuries of the skull. Before the war I operated on a number of traumatic epilepsies with very little success, but I have never hesitated to do an operation which I consider absolutely without risk, since it consists in lifting a permanent or temporary flap in the affected region, and since by following the above procedure I have never had the slightest trouble.

I have likewise had frequent opportunities of operating for this complication among the wounded. I have had neither improvement nor cure except when the convulsive crises were due to localised compression of the brain by a splinter or a foreign body. In every other case I have had only very temporary cures, which some surgeons might have published as permanent ones. Everyone who has had any experience of cerebral surgery knows how easy it is to cure an epileptic for a few weeks or months, and how difficult it is to cure him permanently.

It is certain that a splinter must be removed when

it presses on the brain, but it is absurd to open the dura mater on the pretext of separating adhesions which re-form more firmly than ever after the operation, and I have never done such a thing. For those who show epileptic fits which appear to be directly connected with a cerebral cicatrix I employ radiotherapy, and get good results. The X-rays which make cutaneous cicatrices so wonderfully flexible may very possibly not be without action on cicatrices of the brain.

Radium would probably have an analogous action. If, as I hope, I have some lasting successes by this method to record, I shall not hesitate to facilitate the action of the rays over the whole extent of the cicatrices by cutting an osteo-plastic flap which I shall raise at each application of the radiotherapy. Foreign bodies enclosed in the brain may also be the cause of epileptic crises. Their removal is necessary, but it will only bring about a cure in exceptional cases.

CHAPTER XIX

EXTRACTION OF PROJECTILES

A PROJECTILE in the brain ought to be removed. If it be easily accessible, superficial, and right in the injured area, it is found and removed during the careful cleaning up of the wound. If necessary it can be found by the aid of the fluorescent screen.

If it lies deeply or is in some part of the brain far removed from the damaged area it should be extracted when found by one of the numerous devices for the purpose, which differ from one another more in appearance than principle. When the missile has become lodged in the brain far away from the point of entry and is being well tolerated, there is some risk of infecting its original track afresh if it be removed by the route that it followed, and it is better to remove it by another route. This choice of route must be carefully studied; it must traverse only a silent zone of the brain, and must only involve operative injuries that leave no functional troubles behind. Therefore the surgeon must always have before his mind the position of the various cortical centres, and the course of the fibres running from them.

From this point of view comparison of an examination both before and after operation is instructive, and may sometimes result in giving food for reflection

to the surgeon who looks upon the brain as a homogeneous functionless mass.

It would be well to tattoo three dots which cannot be effaced on the scalp to serve as bench-marks for setting up the localisation apparatus, which I assume to be Hirtz's compass. By the help of this tattooing the wounded man, accompanied by his diagram, can furnish the surgeon under whose care he comes at any surgical centre with the means of discovering the seat of the cerebral abscess which so often develops at the site of a foreign body which has been removed some time previously. If this method were adopted it would be of great service.

Removal of the Foreign Body

The search can be made under the fluorescent screen. This is the best method when the search is carried out through the hole in the skull produced by the projectile and does not go beyond the limits of the damaged area. In this case the jaws of the forceps, which move about freely from side to side and up and down, act in a cerebral pulp which is entirely without value; they destroy nothing. I reject this method entirely when search has to be made for a bullet or piece of shell situated deeply in healthy brain tissue along some other route than that followed by the missile. In this case I prefer the electromagnet to any other procedure when the foreign bodies to be dealt with are magnetic. For this purpose I conceived the idea of using a Hirtz apparatus made entirely of copper, except the indicator probe, which is of soft iron. This probe is passed on to the foreign body, which it locates, and is then magnetised by influence and becomes a withdrawal rod. My friend, Dr Mondain, to whom I submitted this idea, has been good enough to assist

me in working it out, and with the collaboration of M. Malaquin we have been making researches on this subject for the last eight months. We have met with many difficulties, which I hope will soon be surmounted.

My friend, Dr Tanton, has just completed an apparatus on the same principle, which he has presented to the Société de Chirurgie, but he has said nothing about the numerous causes of failure to which I have alluded, nor how to avoid them.

It is difficult to obtain sufficient magnetisation of the withdrawal rod. The idea which naturally occurs to the mind is to make this rod form the core of the electromagnet, but an apparatus with only a very feeble power of attraction is obtained in this way. In order to magnetise the rod powerfully we act by influence, using a very large electromagnet which weighs 80 kilos and has an attraction force of 160 kilos.

It is easy to imagine the difficulties in the manipulation of a delicate instrument of precision created by the introduction of such a mass. M. Malaquin has overcome this difficulty with much ingenuity. In spite of the very powerful magnetisation of the withdrawal rod the latter often lets go the foreign body which it is its duty to bring out.

In order to ascertain exactly what takes place in such a case we have experimented with pieces of shell enclosed in a transparent medium of a consistency identical with the brain substance. We have ascertained that when the projectile comes into contact with the withdrawal rod by a pointed extremity the adhesion is bad; in spite of that, by making several attempts one generally succeeds in bringing out the foreign body.

In a case like this the withdrawal rod must be made to touch the projectile more than once without

pushing the latter deeper down into the brain. For this reason it is necessary to operate under the control

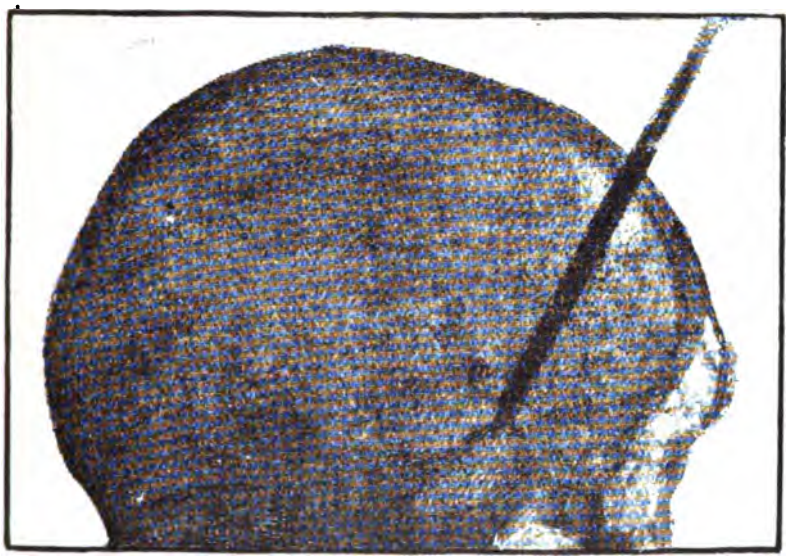


FIG. 58.—Illustration from an article by Cushing showing the magnetised shank missing the projectile and passing by the side of it.

of the radioscope in such a way as to stop immediately contact is re-established.

Fig. 58 is from an article by Cushing, which shows very well the advantage of using a localisation apparatus to guide the withdrawal rod to the foreign

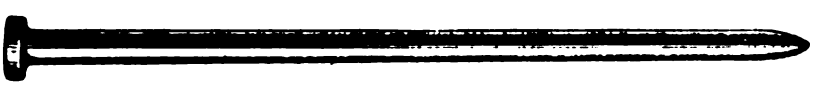


FIG. 59.—Magnetised withdrawal rod used by Cushing.

body. In this figure the magnetised shank is clearly seen to miss the projectile by the side of which it has passed.

Unfortunately this procedure with the electromagnet cannot be applied to leaden bullets, and in this case we replace the magnetised indicator probe

by a rod provided at its extremity with two jaws analogous to those of the forceps for the extraction of foreign bodies from the œsophagus. This forceps must be brought almost into contact with the foreign body, opened, pushed forward, and then closed on it. It can then be drawn out without groping about, and all these manipulations are controlled by the radioscope.

There is nearly always some infected cerebral tissue around the foreign body, sometimes even an abscess, therefore it is necessary to drain by means of a cigarette-drain, which is threaded on to the localising shank of Hirtz's apparatus, so as to get it in a good position (see Abscess on the Brain).

The trephine hole which is to give access to the foreign body will generally be just large enough to allow it to pass, and will not need to be enlarged.

CHAPTER XX

CRANIOPLASTY

For a patient with a wound of the skull the method of operation adopted by all surgeons is to make a large opening in the skull, with the orifice made by the projectile as its centre. From this there result extensive losses in the cranial wall, which do not cause any great inconvenience. However, many of the wounded are concerned about them, and some may even be really inconvenienced; there is nevertheless very seldom any imperative indication for a cranioplasty. Cranioplasty is indicated to protect the brain when it is very widely exposed; in such a case a blow upon the exposed region might have serious consequences. It is also indicated when the loss of substance is situated in the frontal region and entails an unsightly deformity. It should be preceded by a careful examination of the wounded man. Any patient presenting signs of even slight hypertension must have his skull left open; closing the opening may then have troublesome consequences, as I have observed, and as many neurologists have likewise remarked.

Protection for the brain and the re-establishment of the shape of the skull are all that is necessary and all that should be asked for from this operation. It is absurd to employ it to reduce by force cerebral hernias, even when of small volume, and it must not

be expected that it will cause vertigo and the various troubles, which the wounded men attribute to the trephining, to disappear.

Many wounded men have small trephine holes about an inch in diameter which have generally been made for the purpose of exploration. Often the dura mater has not been opened, and the brain can scarcely be seen pulsating in the centre of the hole in the skull. These men do not generally require a cranioplasty, as their brains are practically not exposed. Moreover, the deformity is insignificant when it is at the summit or the sides of the head. It is only in the frontal region that it gives rise to an ugly appearance. In my opinion, therefore, except in the frontal region, cranioplasty is useless for small trephinings, which are much the most frequent, because they have been done on men who had but little the matter with them and have survived. Some few patients who have recovered from very serious skull injuries show large losses of bone over which the skin is often largely replaced by cicatricial tissue which pulsates synchronously with the brain. In these cases protective cranioplasty is certainly indicated, but often it cannot be done. In order to implant successfully a shield of any kind of material under the skin it is necessary to be able to cover it with supple and tough integuments, but in such cases the integuments are generally wanting. I have twice tried to do this, and both times I had much trouble to achieve only a partial success.

Many procedures have been suggested for closing cranial defects. I shall only refer to two—cranial prosthesis by metallic plates, and cranioplasty by the use of costal cartilages, or Morestin's method.

The first of these procedures is well known, and easy to apply if the material and the necessary collaborators are available; it gives good immediate

results, but the metallic plates are not always tolerated indefinitely.

Morestin's procedure, as that surgeon has described it, is excellent, and gives the best æsthetic results. I do not think that it is very efficacious in protecting the brain, because the costal cartilages employed do not weld together well, and do not unite to the bone at all. One, two, or three cartilages are taken—the 6th, 7th, and 8th, or preferably the 7th, 8th, and 9th—and these are used just as they are, or cut into small pieces which, when arranged one on the other, cover up the loss of substance. Morestin has described his procedure at full length in the *Bulletins de la Société de Chirurgie*, and has obtained all the results which he had foretold. I have myself used Morestin's procedure with perfect success.

Gosset, taking up the subject from a special point of view, believed that Morestin's procedure should be modified. Every surgeon having any experience of nerve surgery will be surprised to read what he has written on the subject; I quote textually :—

"For my part, I have said that I prefer to apply to the bone defect a true cartilaginous covering made of a single piece and semi-rigid, this semi-rigidity being in a certain number of cases indispensable to resist the thrust of the brain, and still more to allow of the reduction and the retention of a cerebral hernia.

"In one of my cases, for instance, there was a cerebral hernia half the size of an orange; by means of a large cartilaginous plate, firm and yet pliable, I was able completely to reduce, and keep reduced, this cerebral hernia, the thrust of which was really considerable. With strips of cartilage, and especially with mere chips, the maintenance of the reduction would have been impossible." (*Bulletin Soc. Chirurgie*, March 7, 1916.)

In order to appreciate the surprise which these lines are calculated to produce on a surgeon accustomed to the surgery of the brain, it is enough to know that a difference of a few cubic centimetres more or less in the capacity of the skull, or in the volume of its contents, involves the death of the patient, or, on the other hand, his recovery. Not only compression of but simple pressure on the brain sometimes entails serious accidents, and I do not think that Gosset's method of procedure should be adopted.

Therefore we must keep to Morestin's excellent procedure. Its only drawback is that it requires a preliminary operation, which is not always pleasant for the patient, and may sometimes lead to a serious pleural complication if it be inexpertly done.

In short, I am of opinion that there must be no haste to close in trephine holes, and that the best argument for doing so is the æsthetic one. Morestin's procedure, when it is agreed to by the patient and practised by an expert operator, is very much to be recommended. Metallic prosthesis is difficult to carry out just now, and should be reserved for patients who object to the preparatory operation required by Morestin's procedure.

CHAPTER XXI

LUMBAR PUNCTURE

LUMBAR puncture is of great service in the treatment of patients with skull-wounds, because it is an easy and harmless means of diminishing intra-cranial tension. It must be used with great caution in the early days of the case, for reasons which I have stated already. Later on, on the other hand, it may be repeated more frequently, and it is my custom to do lumbar puncture on subjects with skull-wounds who are on the way to recovery as soon as they complain of headache or vertigo. It will be as well to take advantage of the lumbar puncture to measure the tension of the cerebro-spinal fluid with Claude's manometer. The figure found has only a comparative value, and should be merely compared with the figures obtained later on in the same patient.

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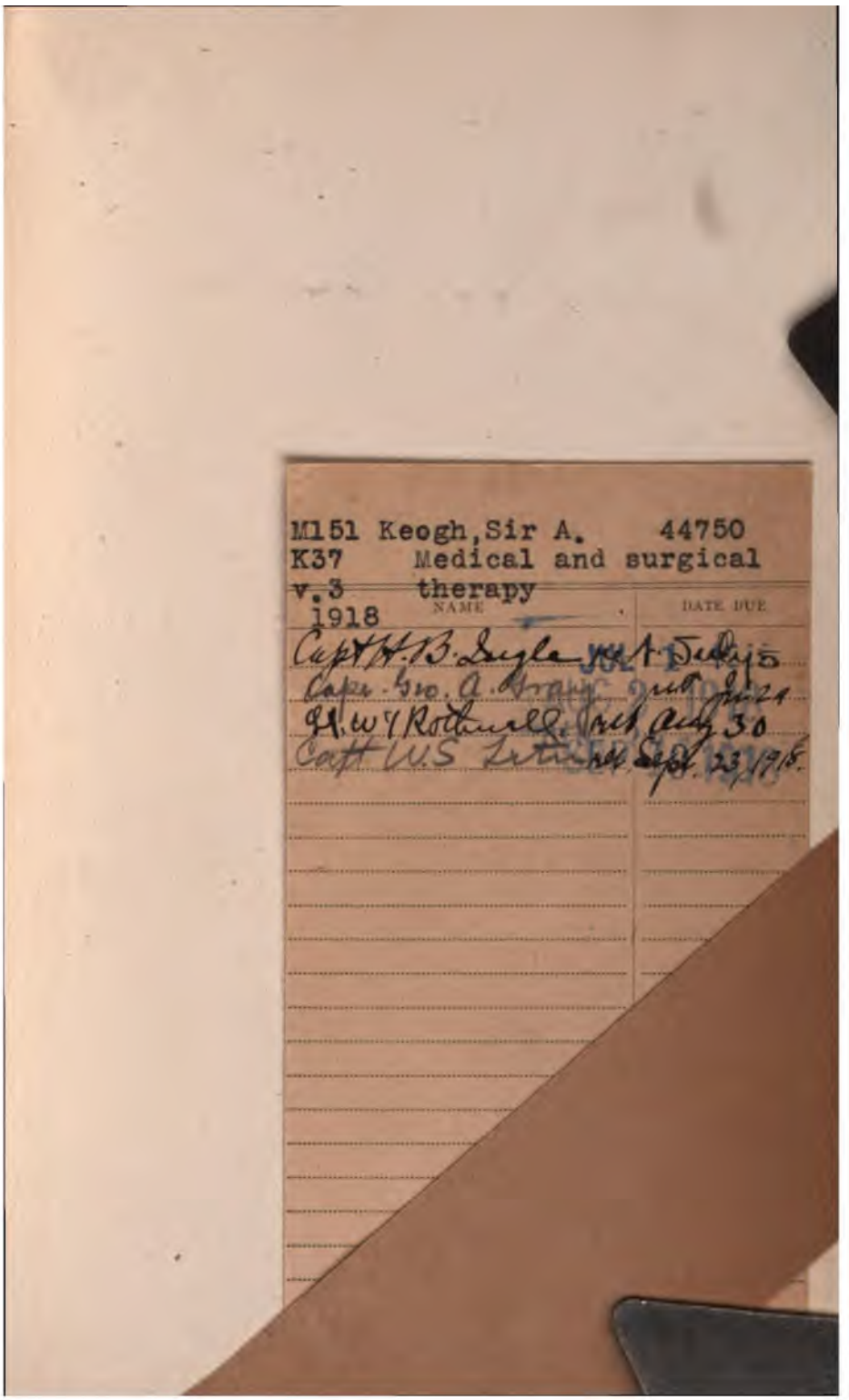

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